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Bull. Nansei Reg. Fish.
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紀伊水道域における魚群分布

花岡藤雄

Distribution of Fish Schools in the Kii Suidō (Channel) Determined by Acoustic Surveys

Fujio HANAOKA

The Kii Suidō is one of the two major channels connecting the Seto Inland Sea through the Pacific Ocean. It comprises the migratory and drifting routes of the commercially important fishes, and their eggs, larvae and juveniles. Acoustic surveys of fish school in the Kii Suidō and there adjacent areas were conducted employing the four research vessels equiped with the echo sounders in November 1973 and June 1974.

Fish schools in November 1974 were most abundant in Kii Suidō and the western outside of this channel, and decreased in following geographical order, the Osaka Bay, the eastern outside of the Kii Suidō and the Harima Nada. Mackerels were dominant in the Kii Suidō and the outside of this channel and small *iwashi*, sardines, anchovies and round herrings, in the Osaka Bay and Harima Nada.

Vertical distribution of mackerel schools in the Kii Suidō agreed with the water mass above 34‰ in salinity in the intermediate layer of southern part of this channel, and that of *iwashi* with the water mass below 34‰ in upper layer of middle and northern parts of this channel.

Compared abundance indices of fish in November with that in June, there were little difference between both in total fish schools, but mackerels in November were above twice that in June, *iwashi* in June were larger than that in November.

紀伊水道は，豊後水道とともに瀬戸内海系水と外洋系水との混合域に当り，内海と外海にまたがって生活するイワシ類等の回遊路で，卵・稚仔魚の補給路でもある（浅見・他　1976）。

この水域では水道中央部及び東部を通って外洋系水が流入することが多く，その勢力は春から夏にかけて強い。内海系水は主として西部沿岸域を通って流出し，秋から冬にかけて卓越する（市栄1952）。この流れに加えて固有の南北方向の潮流がある（海上保安庁　1973）。これらの流れによって起る瀬戸内海系水と外洋系水との混合がひき起す紀伊水道の海洋構造の時空間変化，

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並びにそれに伴う魚卵・稚仔魚及び魚群分布の変化を明らかにすることは漁業資源管理上重要なことである。1973年11月及び1974年6月に科学技術庁特別研究促進調整費による「紀伊水道に関する総合研究」が実施された。本報告ではこの協同研究によって得られた資料を用いて，イワシ類等の魚群分布と，それらが海洋環境とどのように関連しているかについて報告する。

本研究のため海上での調査に当られた，徳島県水産試験場試験船とくしま，和歌山県水産試験場試験船きい，南西海区水産研究所調査船しらふじ丸及びこたか丸の乗組員並びに調査員の各位に厚くお礼申し上げる。本研究をまとめるに当って，ご指導とご校閲をいただいた外海資源部佐野蘊部長，同古藤力第一研究室長，及び種々ご助言をいただいた同小西芳信技官に厚くお礼申しあげる。

調査及び解析の方法

本研究のための海洋観測と魚群調査は，1973年11月11～16日と1974年6月13～22日に実施された。今回の調査に参加したしらふじ丸，こたか丸，きい，とくしまの魚群探知機は，漁船に広く用いられているもので，その型式や主要性能等はTable 1に示すとおりである。1973年11月の調

Table 1　Echo-sounders on boad of the research vessels.

Name of vessels	Gross tonnage	Echo-sounders		
		Type	Cycles	Depth range
SHIRAFUJI-MARU	93.7	FURUNODENKI-FUG	28KHz	0–100m
KOTAKA-MARU	47.5	FURUNODENKI-FHG	28KHz	0–100m
KII	34.8	SANKEN-NSE	28KHz	0–130m
TOKUSHIMA	76.5	FURUNODENKI-FUG	50KHz	0–100m

査は，徳島県蒲生田崎，和歌山県日の岬から淡路島南岸沖に至る紀伊水道内において，東西を横断するD, D′, E, E′, F, F′, G, G′の8つの定線を，南北にほぼ2.5浬間隔で設定した(Fig. 1)。この時の各調査船の航程はTable 2に示すとおりで，とくしまはD→D′，こたか丸はE→E′，きいはF→F′，しらふじ丸はG→G′を，日出から日没までの昼間に毎日1回ずつ，11日から16日まで連続6回（但し，しらふじ丸は13日から16日まで4回）調査した。1974年6月に

Table 2　Sequences of observations conducted by four research vessels, 11–16 November 1973.

Vessel / Date	SHIRAFUJI-MARU	KII	KOTAKA-MARU	TOKUSHIMA
Nov. 11	—	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′
〃 12	—	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′
〃 13	st. G1→G6→G5′→G2′	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D→5D4′→D0′
〃 14	st. G1→G6→G5′→G2′	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′
〃 15	st. G1→G6→G5′→G2′	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′
〃 16	st. G1→G6→G5′→G2′	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′

Arrows denote order of observations.

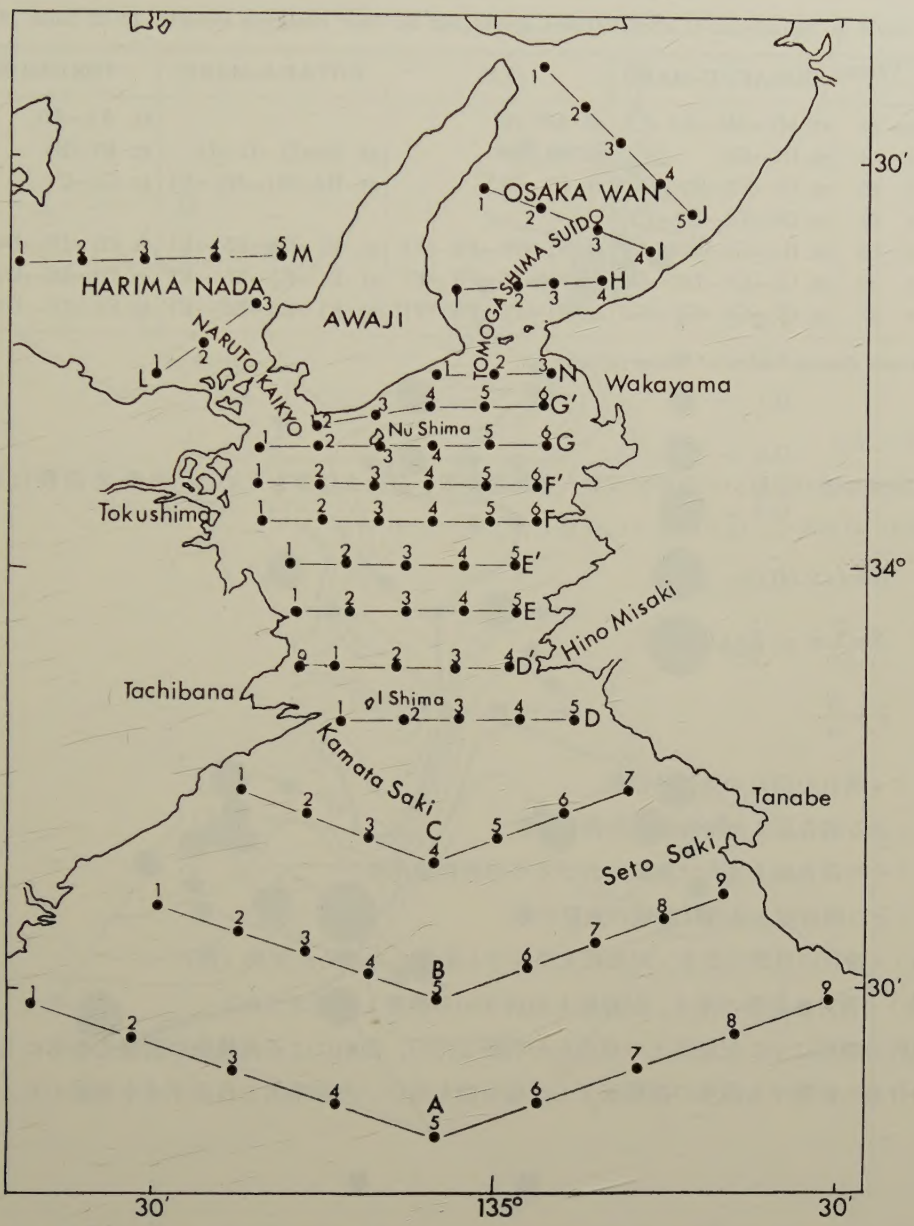

Fig. 1 Oceanographic stations occupied in November 1973 and June 1974.

おける各調査船の航程は Table 3 に示すとおりで，19日から22日の間に3回，1973年11月と同じ調査船が同じ定線を調査した。この他に6月13日から16日にかけては，紀伊水道の隣接海域である播磨灘（M，L 線），大阪湾及び友ヶ島水道南部（H，I，J，N 線），紀伊水道外域の西部（A_{1-5}，B_{1-5}，C_{1-4}），同東部（A_{6-9}，B_{6-9}，C_{5-7}）及び紀伊水道内のD，E，F，G 線を，上記の4隻の調査船がそれぞれ分担して1回ずつ調査した。

各調査定点においては，測深，各層水温・採水等の観測並びに，魚卵・稚仔魚及びプランクトンの採集を行った。各定点間を航走中は常時魚群探知機を作動させ，分布する魚群の記録を得る

Table 3　Sequences of observations conducted by four research vessels, 13–22 June 1974.

Vessel / Date	SHIRAFUJI-MARU	KII	KOTAKA-MARU	TOKUSHIMA
June 13	st. M1→M5→L3→L1	st. A9→A6	—	st. A1→A5
〃 14	st. G1→G5	st. B9→B6	st. J5→J1→I1→I4	st. B1→B5
〃 15	st. F6→F2→E3→E5	st. C7→C5	st. H4→H1→N3→N1	st. C1→C4
〃 16	st. D5→D1→E2→E1	—	—	—
〃 19	st. G1→G6→G6′→G2′	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′
〃 20	st. G1→G6→G6′→G2′	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′
〃 22	st. G1→G6→G6′→G2′	st. F1→F6→F5′→F1′	st. E1→E5→E5′→E1′	st. D1→D5→D4′→D0′

Arrows denote order of observations.

ようにした。

魚群探知機の記録から魚群出現数，魚群量指数，遊泳水深等を求めた。魚群量指数は横田他（1953）の方法で，以下のように計算した。

$$si = Li \times Hi$$

$$S = \sum_{i=1}^{n} si = \sum_{i=1}^{n} (Li \times Hi)$$

$$\bar{s} = \frac{S}{n}$$

si ；i 番目の群れの魚群量指数

S ；ある調査線または海域の魚群量指数

$\bar{s}$ ；その調査線上または海域における平均魚群量指数

n ；その調査線上または海域の魚群の数

Li ；i 番目の魚群の長さ，記録紙上の長さと船速から求めた実長（浬）

Hi ；i 番目の魚群の厚さ，記録紙上の高さから換算した厚さ（m）

魚群の種類は主に記録紙上の形状から判断したが，漁船による漁獲物の情報も参考にした。魚群の分布に影響する環境の指標値として塩分値を用い，内海系水と外洋系水を判断した。

結　　果

魚群の分布状況

1．紀伊水道及びその隣接域における魚群の水平分布

1974年6月13～16日に調査した紀伊水道とその隣接域の大阪湾，播磨灘及び水道外域における魚群の分布状況を Fig. 2 に示す。等塩分線は魚群の主分布層である30m層で示すのが妥当であるが，この層の観測値が欠除している水域があるため，表層の塩分値を用いた。等塩分線の分布からこれらの海域全般の海況をみると，水道外域では，東部から外洋系水とみられる34‰台の高かん水が水道南部域へ流入している。水道内では東部域が高かん水帯となっているが，西部域には33‰以下の低かんな沿岸水帯が存在し，沿岸域を南下している。このため，水道南部の蒲生田

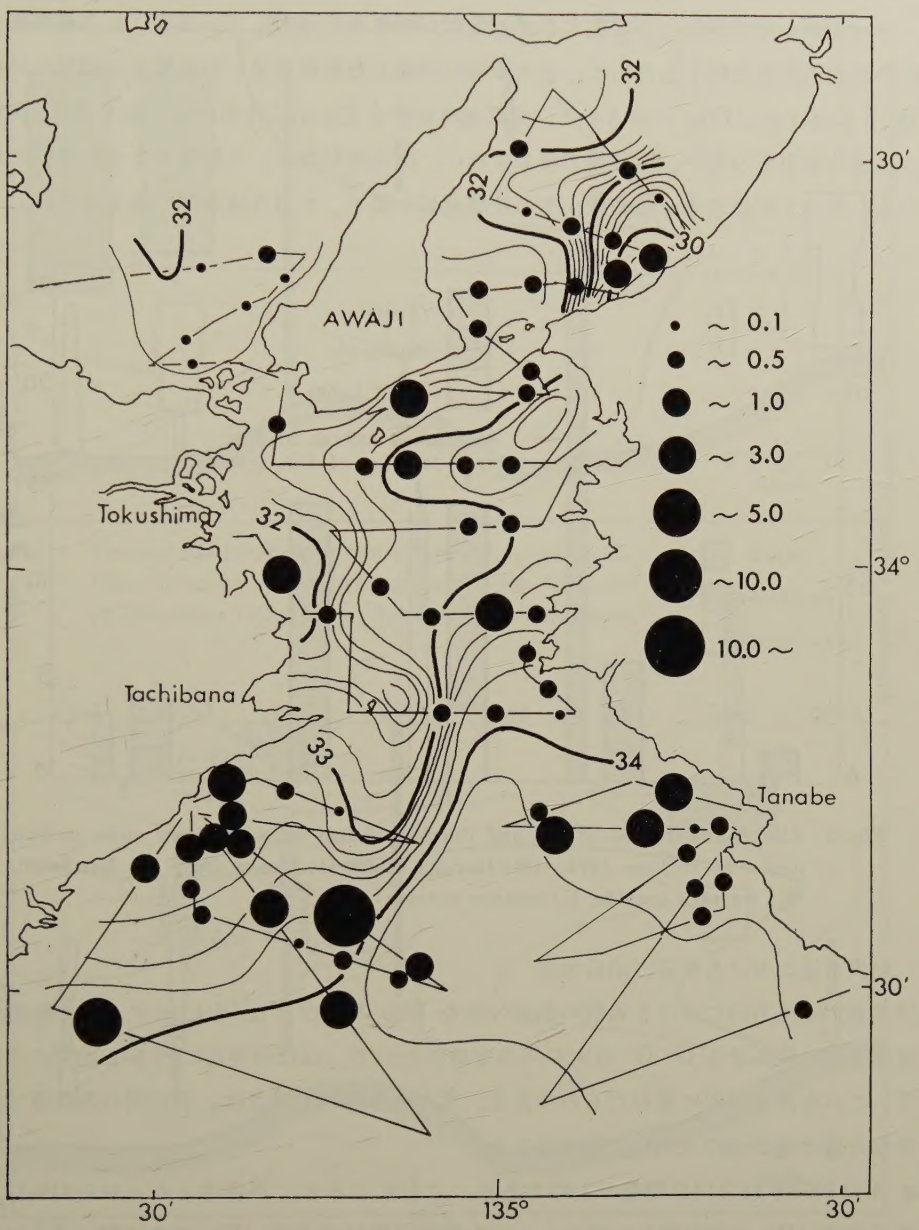

Fig. 2 Abundance indices of fish schools along interstation lines, 13–16 June 1974.

埼～日の岬の中間付近は東西方向の塩分傾度が大きく，沿岸水帯と外洋水帯との境界となっている。水道隣接域では，播磨灘で32‰台の低かん水帯が分布している。大阪湾では南東部の沿岸域から30～31‰の低かん水帯の張出しがみられ，沿岸から沖合にむけての塩分傾度が大きい。

魚群の分布をみると，水道外域では西部に多く，東部では少ない。これらは主としてサバ類群と推定され，33～34‰台の比較的高かんな水帯に分布している。水道内では，高かんな外洋水が影響している南東部域でサバ類群と推定されるものが主に分布し，西部沿岸の低かんな水域には主にイワシ類群と推定されるものが分布している。播磨灘における魚群の分布は少なく，大阪湾

ではイワシ類のシラス，カエリと推定される魚群がやや多く分布している。これら各水域について魚群の分布密度を比較するために，各水域別に出現した魚群量及び魚群数を10浬当りに換算して Fig. 3 に示した。Fig. 3 によると，魚群量は紀伊水道と水道外域西部で最も多く，次いで大阪湾，水道外域東部の順で，播磨灘で最も少ない。次に魚群数は，大阪湾でとくに多いのが目立っている。次いで紀伊水道，播磨灘，水道外域東部の順で，水道外域西部で最も少ない。

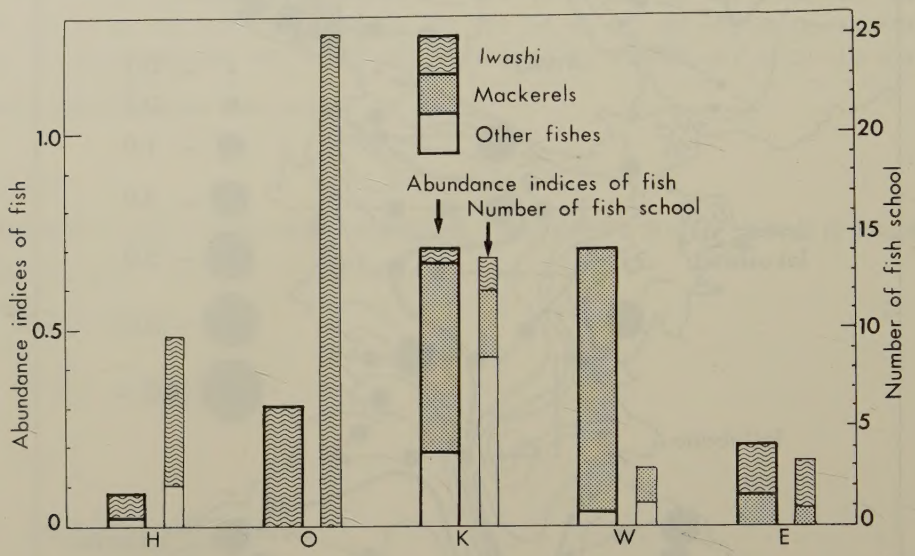

Fig. 3　Abundance indices of fish and number of fish school per ten miles in five areas, 13–16 June 1974. (H; Harima Nada, O; Osaka Bay, K; Kii Suidō, W; western outside, E; eastern outside)

2.　紀伊水道における魚群の鉛直分布

紀伊水道の南北方向における魚群の鉛直分布を Fig. 4 及び Fig. 5 に示す。この鉛直分布図は，東西方向に横断する D～G′ の 8 本の各定線のなかで，ほぼ中央部に当る 2 点間の魚群量を用いて，これを南北方向に連ねたものである。図中の魚群の大きさは，2 点間の魚群量で示した。一方等塩分線は各 2 点の平均塩分値で示した。

Fig. 4 は1973年11月14日調査のものである。これによると，外洋水とみられる34‰以上の高かん水が南部（D）の中底層から流入し，34‰等塩分線は中北部（F′）の中下層に達している。そして F′～G 付近で低かんな沿岸水と接し，この付近で南北方向の塩分傾度が大きくなっている。魚群は，高かんな外洋水の影響が強い南部の D，D′ の上中層にサバ類と推定される大きな群れが分布している。その北側の E～F の上中層のやや低かんな水帯にはイワシ類と推定される小型の群れが分布している。南部の D～D′ 及び北部の G′ 付近の中底層には，サバ類，イワシ類以外の魚群が分布している。この魚群は漁船の漁獲物情報からみて，タチウオが主体であると推定される。Fig. 5 は1974年 6 月19日調査のものである。Fig. 4 の11月に比較して上中層における鉛直方向の塩分傾度が大きい。E 付近では沿岸から流出してきた低かん水が上層に分布している。34‰以上の高かん水は11月と異なり南部の上層部には存在せず，約30m層以深の中底層から

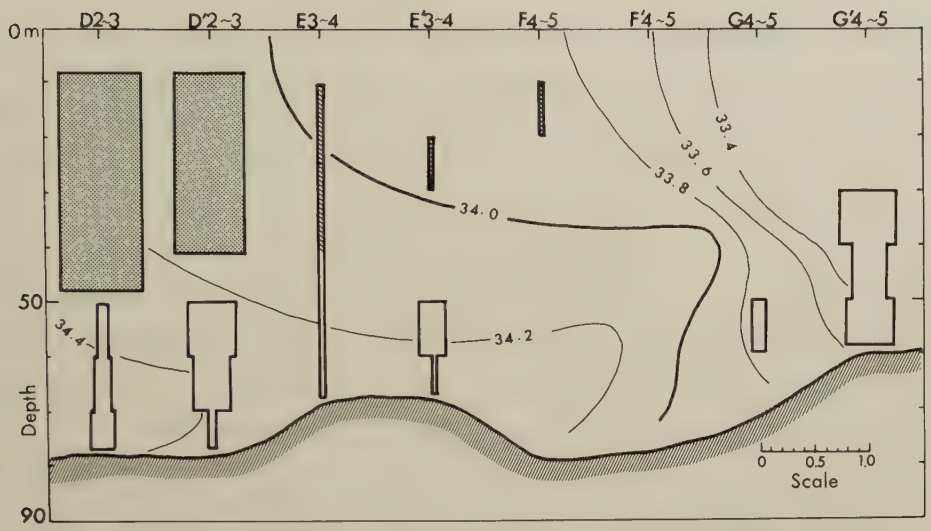

Fig. 4 Vertical distribution of fish school and isohaline (‰) from northern to southern parts in the Kii Suidō, 14 November 1973. (Scale; Indices of fish abundance)

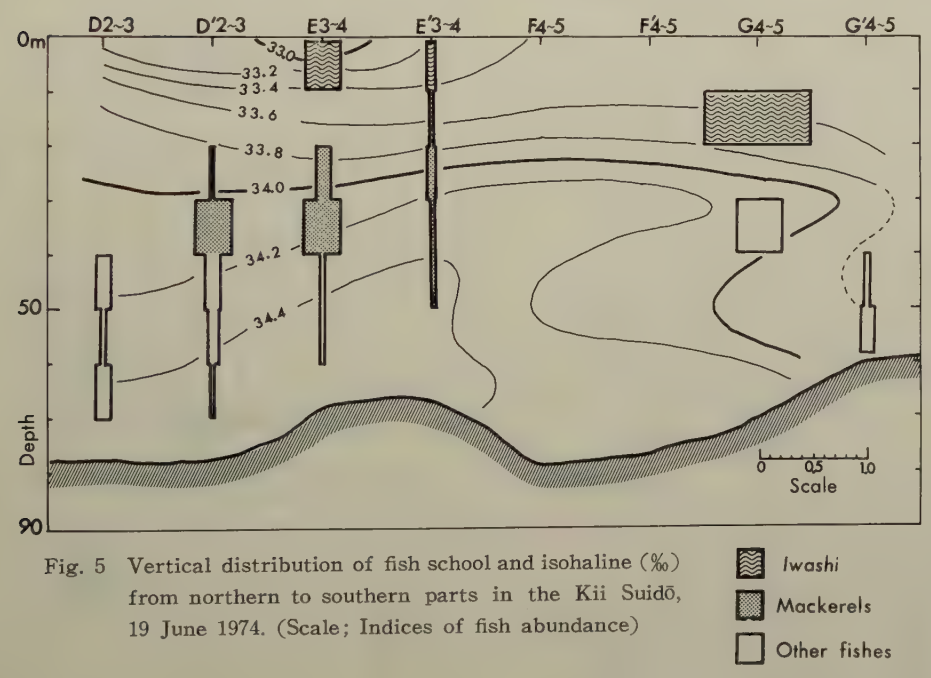

Fig. 5 Vertical distribution of fish school and isohaline (‰) from northern to southern parts in the Kii Suidō, 19 June 1974. (Scale; Indices of fish abundance)

水道内へ流入し，北部のG付近の中底層に達している。魚群は，サバ類と推定されるものがD′，E付近の，中層の塩分34‰台の高かんな水帯に分布しているが，11月に比べて少ない。イワシ類と推定されるものは，E，E′及びGの，上層のやや低かんなところに分布しており，11月に比べて多い。その他のタチウオ主体と推定される魚群は，南部のD～E及びG，G′の高かんな中下層にみられる。

魚群の分布とその短期変化

紀伊水道内で調査した1973年11月の6回，1974年6月の3回について各回毎の魚群分布を，イワシ類群（主に上～中層に分布），サバ類群（主に中層に分布），及びその他の魚群（主に底層近くに分布し，タチウオが主体と考えられる）の3つに大別して Fig. 6～Fig. 11 に示した。また，各回の魚群量の日変化を Fig. 12 に示した。

魚群分布の概要；1973年11月11～16日間の6回の調査を，11～12日，13～14日，15～16日の3つに区分して図示した。したがって魚群量及び等塩分線の値は2日間の平均をとった。Fig. 6 にイワシ類主体の魚群分布を示した。等塩分線は30m層である。魚群は34‰等塩分線から北西側の低かんな水域に分布し，この調査期間における分布域の大きな変化はなかった。Fig. 7 にサバ類主体の魚群分布を示した。等塩分線は30m層である。イワシ類主体の魚群に比べて量的に多

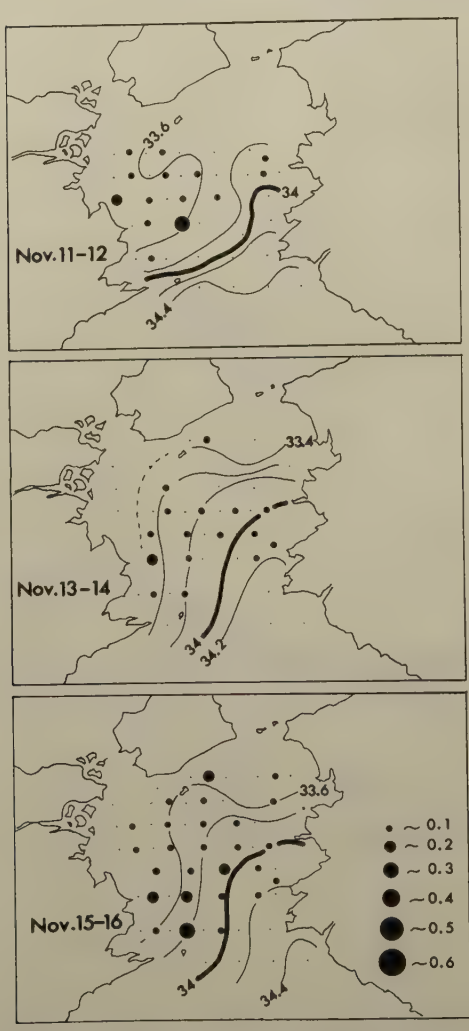

Fig. 6　Distribution of *iwashi* fish school on each day in Kii Suidō, 11–16 November 1973. (Isohaline is 30m layer)

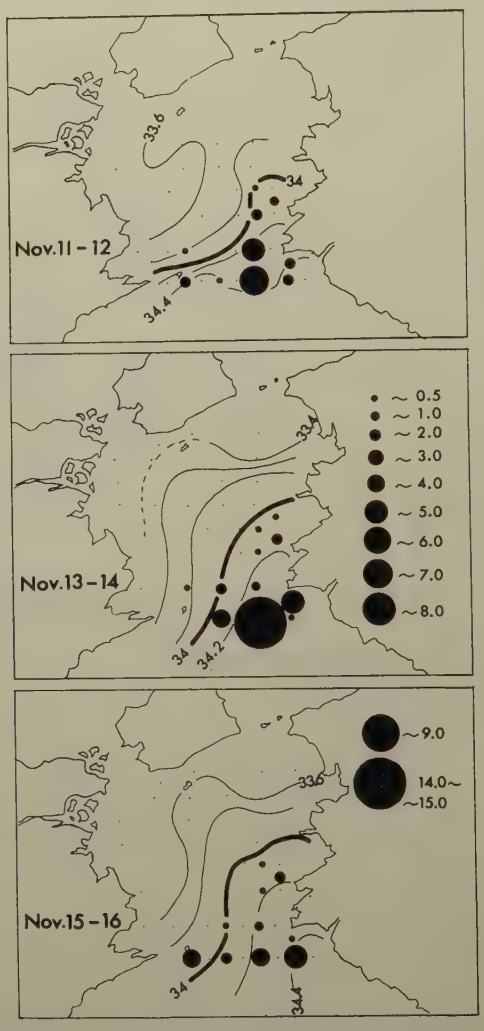

Fig. 7　Distribution of Mackerels fish school on each day in Kii Suidō, 11–16 November 1973. (Isohaline is 30m layer)

く，分布域も34‰等塩分線より高かんな水道南東部域となっている。Fig. 8 にその他の魚群の分布を示した。等塩分線は底層である。この等塩分線の分布をみると，水道中央線にそって34‰以上の高かん水が南から北上しており，魚群はこの高かん水帯のなかに多く分布している。

1974年6月19，20，22日の3回の調査のうち，イワシ類主体の魚群分布を Fig. 9 に示した。等塩分線は30m層である。等塩分線の分布をみると，34‰以上の高かん水帯が水道南東部から北上し，北部まで達している。水道西側は33‰台の低かん水帯が張出し，東西方向の塩分傾度が大きい。魚群は34‰等塩分線よりも低かんな西側に多い。19日には北東部沿岸にも多い。Fig. 10 にはサバ類主体の魚群分布を示した。等塩分線は30m層である。魚群は主に34‰以上の高かんな水帯に分布している。Fig. 11 にはその他の魚群の分布を示した。等塩分線は底層である。34‰以上の高かん水帯は30m層よりも北上勢力が強く，水道北部にまで達している。魚群は主にこの

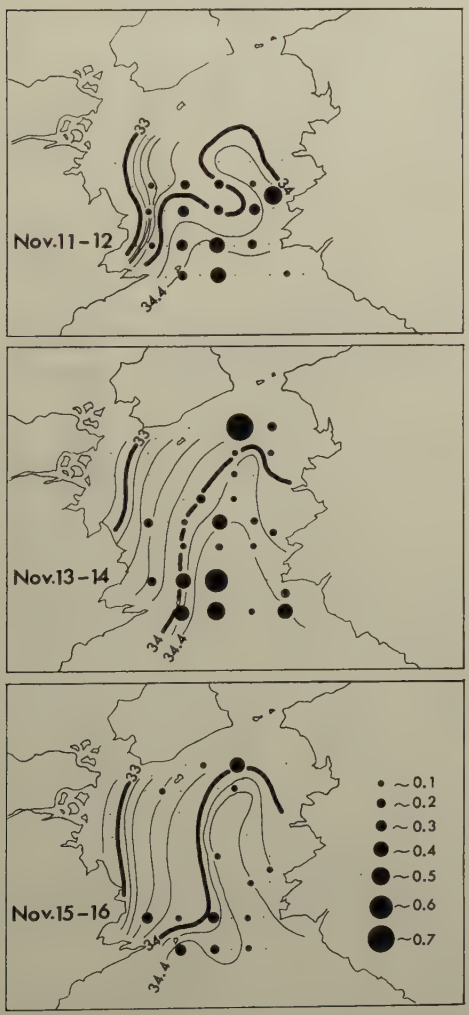

Fig. 8 Distribution of other fish school on each day in Kii Suidō, 11–16 November 1973. (Isohaline is bottom layer)

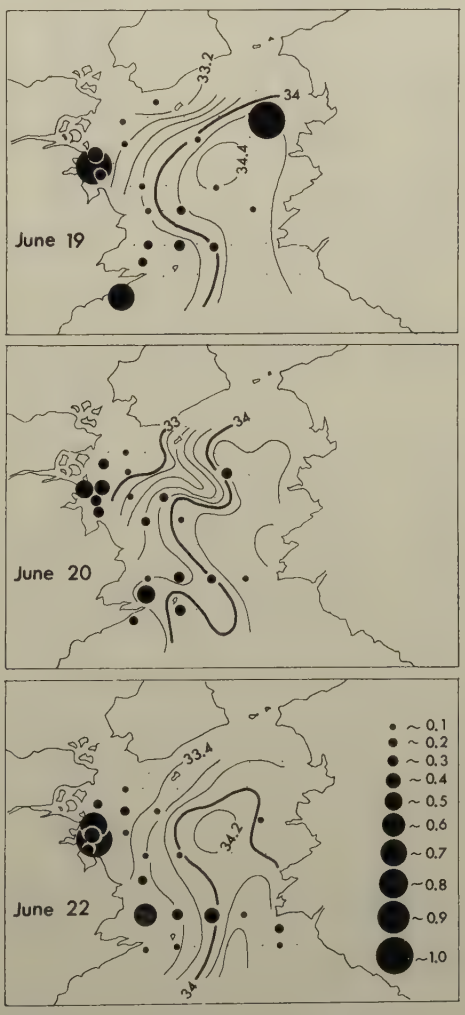

Fig. 9 Distribution of *iwashi* fish school on each day in Kii Suidō, 19–22 June 1974. (Isohaline is 30m layer)

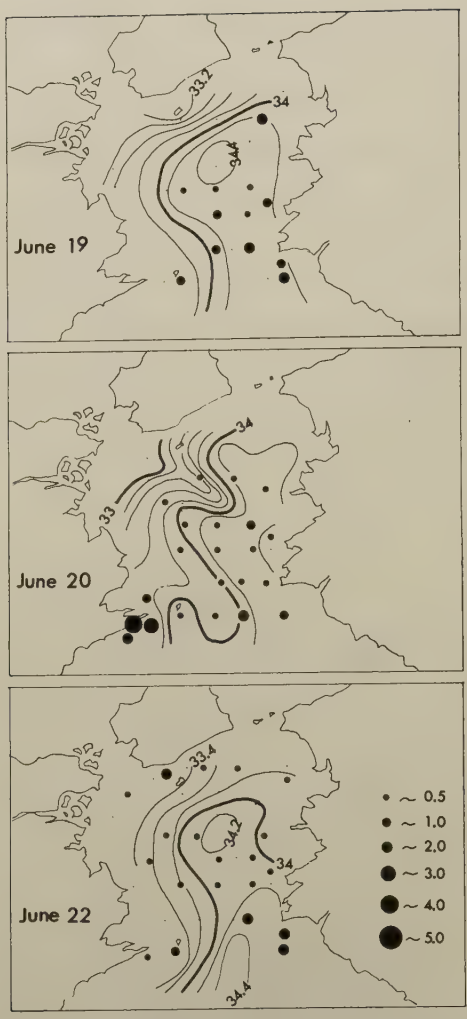

Fig. 10　Distribution of Mackerels fish school on each day in Kii Suidō, 19–22 June 1974. (Isohaline is 30m layer)

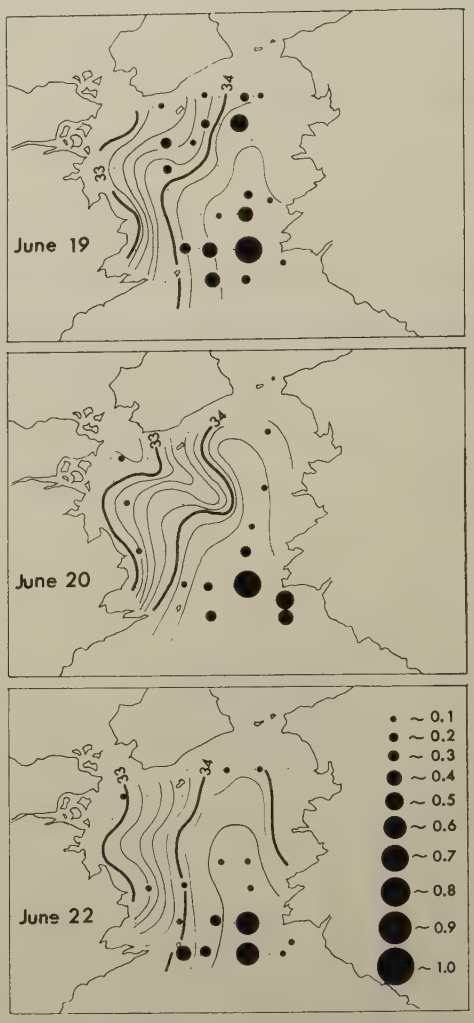

Fig. 11　Distribution of other fish school on each day in Kii Suidō, 19–22 June 1974. (Isohaline is bottom layer)

高かん水帯中に分布している。

魚群量の日変化；Fig. 12 に示した日別の魚群量は，各調査日毎に水道全域で記録された魚群量を，調査した定線の数（8本または6本）で除した平均値である。Fig. 12 によると，11月11～16日の6日間においては，全魚群量，イワシ類主体の魚群量及びサバ類主体の魚群量とも日変化は少ない。しかし，その他の魚群では調査初期の11日及び後期の15，16日に比べて，中期の12～14日の魚群量は約3倍と多くなっている。6月における3日間の調査では，すべての魚種とも日変化は小さい。

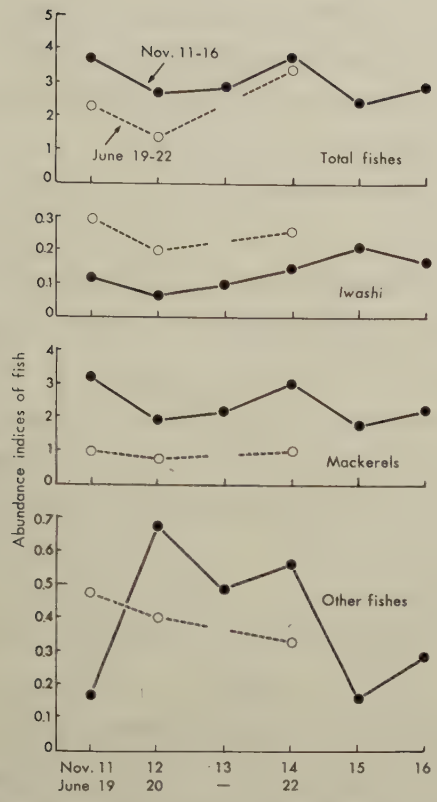

Fig. 12 Daily changes of abundance indices of fish in the Kii Suidō, November 1973 and June 1974.

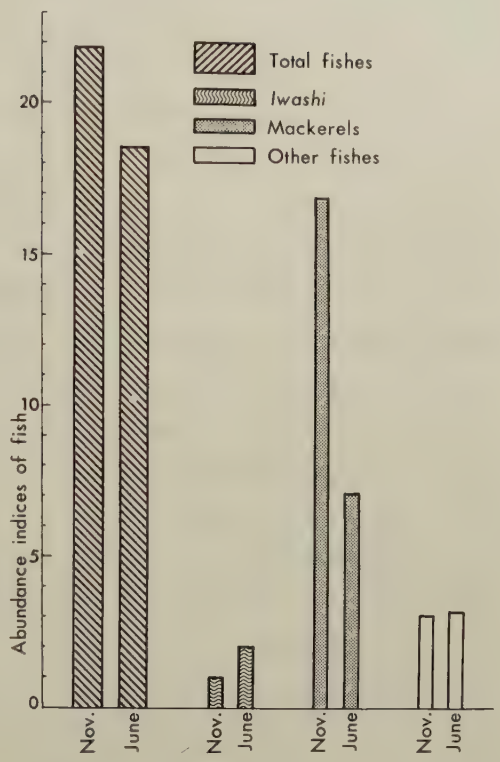

Fig. 13 Comparison of abundance indices of fish in November 1973 and June 1974 in the Kii Suidō.

魚群量の季節的な変化

初冬季に当る1973年11月と，初夏季に当る1974年６月の調査時における魚群量を Fig. 13 に示した。この魚群量は，それぞれの調査時期の１回調査当りの平均魚群量である。これによると，全魚群量では11月の方が６月よりやや多い程度であるが，魚種別にみると，最も多いサバ類主体の魚群量が，11月は６月の２倍以上多くなっているのが特徴的である。魚群量の少ないイワシ類主体の群では６月の方が多く，その他の魚群では11月，６月ともほぼ同程度の魚群量となっている。

考　　察

紀伊水道及びその隣接海域を含めた1974年６月の調査によると，水道外域及び水道内の東部域に外洋性のサバ類魚群が多い。これらのサバ類は，外海域で発生したものが外洋系水の影響の強い水道外域や水道内の東部に来遊したものと考えられる。サバ類に比べて沿岸性のカタクチイワシやマイワシ等の群は，水道西部の沿岸水帯に分布している。大阪湾ではカタクチイワシのシラスまたはカエリと推定される群が，低かん水の張出しが強い沿岸域に分布している。これは一般

にイワシ類のシラス期には，河川水の影響が強い低かんな沿岸域に集る傾向が強い（浅見1962，神浦1966）ことによるものと考えられる。各水域における魚群量と魚群数の出現状況（Fig. 3）をみると，主として水道外域に分布するサバ類魚群は，魚群量が多いにもかかわらず魚群数は少ない。このことは，外海域に分布するサバ類は個々の群れが大きく，集群性が強いことを示唆するものである。これに対して分布している魚群の大部分がイワシ類のシラス，カエリと推定される大阪湾では，魚群量が少ないにもかかわらず魚群数が非常に多い。つまり，小さな群れのものが数多く分布していることを示すものである。豊後水道及びその周辺域においても，外洋系水の影響が強い南部の魚群は群れが大きく，北部の沿岸水域ほど小さい（花岡1983）と報告しており，紀伊水道周辺域でもこれと同じ傾向であるといえる。

紀伊水道内の南北方向における塩分の鉛直分布（Fig. 4，Fig. 5）をみると，高かんな外洋系水が南部の中底層から水道内へ流入し，低かんな沿岸水は上層に分布している。これは山田・他（1977）が，DIN（全無機態チッソ）の分布から外洋系水が底層から水道内へ流入し，沿岸水は表層から流出していると報告していることとよく合致するものである。このような海洋環境のなかで魚群の鉛直分布は，外洋性のサバ類は水道南部の中層に多く，とくに11月は6月に比べてより南部に多く分布する特徴がみられる。これは紀伊水道周辺海域におけるサバ類の季節的な移動回遊（日本水産資源保護協会1974）のなかで，11月は水温下降期の初冬季に当るため，瀬戸内海や水道中北部に分布していた魚群が南下して，外洋系水の影響の強い南部域に集群したものと考えられる。沿岸水の影響の強い上層にはイワシ類の魚群が分布し，なかでも6月に多い。この頃の漁船による漁獲物情報から，これらの魚群はその年の冬春季に発生したマイワシ当歳魚が主体と考えられ，春，夏季にかけてこの沿岸に来遊したものと考えられる。タチウオが主体とみられるその他の魚群は，高かんな南部の中底層に多いが，低かんな北部の中底層にも多いことから，塩分の高低が分布に及ぼす影響はあまり大きくないと考えられる。また，この調査を実施した1973年11月におけるタチウオとみられる魚群の分布様相と，タチウオ底曳漁船の漁場形成場所がよく一致している。

11月の6日間及び6月の3日間のなかでの魚群量の日変化は，イワシ類やサバ類の魚群では小さく，この程度の短期間では紀伊水道内外への移動は少ないことが推定された。しかし，11月におけるタチウオを主体とするその他の魚群の日変化は前2者に比べて大きく，水道内外への移動が短期間に行われていることを示唆するものといえよう。

初冬季に当る11月と，初夏季の6月に出現した魚群量（Fig. 13）をみると，両者ともサバ類の占める割合が大きい。これは1965年以降，四国周辺海域で増加が著しくなったサバ類資源の状態（南西水研1975）を反映しているといえよう。11月と6月を比較してみると，6月に比べて11月の魚群量が多いのが目立っている。これは前にも述べたように，初冬季になって南下したものが水道南部に集群したためとみられる。イワシ類の魚群量は，11月，6月とも少ないが，両者を比較すると6月の方が多くなっている。6月の魚群はマイワシ当歳魚とみられ，春季から夏季にかけて水道沿岸域に来遊したため，量的に11月を上回ったものと考えられる。タチウオを主体とするその他の魚群では，11月，6月ともほぼ同じ魚群量である。紀伊水道域で最も多くタチウオ

を漁獲する底曳網による1973，1974年のタチウオ漁獲量の季節変化（和歌山水試1976）をみると，主漁期は5月～11月で夏季に漁獲量の山があり，この調査時期に当る11月と6月の漁獲量はほぼ同じである。魚群量もこのことを反映していると考えられる。

摘　　要

1973年11月及び1974年6月に魚群探知機を用いて，紀伊水道及びその周辺域における魚群の分布状況を調査した。その結果を要約すると次のとおりである。

1974年6月に調査した紀伊水道及びその隣接海域における魚群分布は，紀伊水道及びその外域の西部で多く，次いで大阪湾，水道外域東部，播磨灘の順であった。紀伊水道とその外域ではサバ類主体，大阪湾と播磨灘ではイワシ類が主体であった。

紀伊水道内における魚群の鉛直分布をみると，34‰以上の高塩分が存在している水道南部の中層ではサバ類が多く，それ以下の低塩分が存在する水道中北部の上層ではイワシ類が多かった。

1973年11月に6日間及び1974年6月に3日間ずつ調査した結果，この短期間での魚群量の日変化は，イワシ類及びサバ類では小さく，その他の魚種においては6月に小さかったが，11月では大きかった。

11月と6月の魚群量を比較すると，全魚群量では両者において大差はないが，魚種別ではサバ類の魚群量が11月には6月の2倍以上であった。イワシ類では6月の方が11月よりも大きい値を示した。

文　　献

浅見忠彦，1962；太平洋南区のカタクチイワシ *Engraulis japonica* (Houttuyn) に関する研究．南水研報，16，1—55.

浅見忠彦・小西芳信・中沢すみ子，1976；魚卵・稚仔の分布とその変化．内外水交換機構の生物生産力に与える影響解析，科学技術庁，30—39.

花岡藤雄，1983；豊後水道域における魚群分布．南西水研報，15，13—27.

市栄　誉，1952；紀伊水道の海況（1951年）．中央気象台海洋報告，2(3)，35—60.

海上保安庁，1973；昭和48年潮汐表第1巻.

神浦藤雄，1966；魚探記録からみたカタクチ群の大きさと出現状況について．南水研報，23，31—42.

南西海区水産研究所外海資源部，1978；南西海区長期漁況予報の検討資料.

日本水産資源保護協会，1974；徳島県新長期総合開発の水産資源および漁業・養殖業に及ぼす影響に関する調査報告書.

和歌山県水産試験場，1976；最近の紀伊水道タチウオの資源状態について．昭和50年度底魚資源調査経過報告，昭和50年3月南西海区水産資源調査担当者会議資料.

山田　久・坂本久雄・久岡　実，1977；紀伊水道域における海況の短期変動に関する研究．南西水研報，10，33—52.

横田滝雄，1953；日向灘豊後水道のイワシ類の研究．南水研報，2，128—231.

南西水研報
Bull. Nansei Reg. Fish.
Res. Lab. No.18, 1985

ホンダワラ藻場造成に関する研究—Ⅰ
ヤツマタモク親藻移植による藻場造成※

吉 川 浩 二

Studies on the formation of *Sargassum* beds. I
The formation of artificial *Sargassum* beds by a transplant of matured *Sargassum patens* C. AGARDH

Kôji YOSHIKAWA

Sargassum beds formations were carried out by placing an artificial reef with matured *Sargassum patens* and by covering over it with "Nori" cultivation nets, in the natural *Sargassum* beds at Matsugahana point, Towa-chyo, Yashiro island of Hiroshima bay.

The following results are obtained;

1. Young plants of *S. patens* were found on the blocks in 3 months later, on September 13, 1982, and grew to thalli, thereafter. Main branches had decayed and gone, leaving a root area behind on March through May. Then, new plants came out from the root area and grew faster during October to next January. The plant showed maturing on March and diminished away during summer.
2. *S. patens* formed vegetation, showing the maximum standing crops of 100 individuals/m^2 and 6050.0g wet weight/m^2 on January 7, 1984.
3. The *Sargassum* beds expanded slowly during about 9 months from August 4, 1982 to May 19, 1983 and quickly during about 10 months from May 19, 1983 to March 21, 1984. The reason for quick expand on the latter, may depend on the regeneration of remained roots.
4. The maximum growth rate of tagged adult *S.patens* was 3.9 mm/day during about 7 months from October 12, 1982 to May 19, 1983. A survival rate of tagged adult *S. patens* was 30% on this duration.
5. A period of maturation of *S. patens* was not made clear on the artificial reef, thought it was assumed to be on March to June by the fact of changing the colour at main branches.
6. The method of covering matured *S. patens* with "Nori" cultivation nets were assumed to efficient on keeping the plants on the blocks and preventing them from flowing away.

1984年10月12日受理，南西海区水産研究所業績第156号，〒739—04，広島県佐伯郡大野町
※ 本研究はマリンランチング計画にもとずいた成果である。MRP82—Ⅲ—6—7。

日本沿岸海域に分布するホンダワラ類を中心とした海藻群落は沿岸水産資源の再生産に重要な役割を果している。このホンダワラ群落は過去数年に海域の富栄養化や埋立のため衰退している。このためホンダワラ群落の造成，拡大，維持，管理に関する技術の確立は水産分野では重要な課題となっている。

筆者（1981，1982，1983）は1980年から瀬戸内海の各海域に試験漁場を数ケ所設定し，ホンダワラ類の生長や成熟およびその群落の季節的変化などの調査，研究を数年間実施してきた。そして，これらの生態観察の結果をもとに，1982年以来，親藻や種苗の投入によりホンダワラ藻場の造成を試みている。

本報告はその内から，ヤツマタモクを対象とした藻場造成について，その結果をとりまとめたものである。

本研究は，昭和56～58年度水産庁特別研究費“近海漁業資源の家魚化システムの開発に関する総合研究（マリーンランチング計画）”でなされたものである。研究の機会を与えて下さった関係各位に感謝する。

本研究を行うにあたり，種々の御指導と本報告の校閲を賜った当水研増殖第二研究室長月舘潤一博士に感謝する。また，研究上の便宜をいただいた山口県外海水産試験場増殖科長中村達夫氏と，山口県東和町漁協組合組合長風呂川盛勝氏はじめ組合理事諸氏に感謝の意を表する。さらには，直接潜水調査に従事するとともに，有益な御助言を頂いた徳山アクアサービス K.K. 石丸正氏に対して厚く御礼申上げる。

材料と方法

造成試験は Fig. 1 に示す山口県大島郡東和町伊保田松ケ鼻地先で行った。

用いた人工基質は Fig. 2 に示す特枡型コンクリート・ブロック（50×50×75㎝，空中重量300 kg，以下藻礁と呼称する）である。

1982年５月19日に20基の藻礁を設置し，その後，５月31日に生殖器床上に多数の成熟卵を有したヤツマタモクの親藻を藻礁上に置き，その上をのり網で被覆した。

供試したヤツマタモク親藻は1982年５月６日と18日に山口県長門市深川湾で採集し，直ちに大型水槽で保存培養したものである。

調査は２～３ケ月ごとに１回の割合で実施し，個体の生長，成熟及び生育密度を観察した。また，群落形成の経過をみるため他の海藻の種組成も調べた。

生長は最大主枝長と湿重量で観察し，成熟は形態や色の変化，生殖器床の有無を調べ，生育密度はm^2あたりの藻体本数及び重量であらわした。藻礁上の生長観察は着生数が多いとき10×10㎝枠を用いたが，着生個体数が減少するに従い20×20㎝，25×50㎝，50×50㎝枠を順次使用した。

なお，生長の観察は標識をつけた個体についても行った。

本試験海域は岸盤および転石帯が約25％，砂質帯が約75％の割合からなりたっており，岸盤および転石帯にはホンダワラ類を主とした群落が形成されている。藻礁を設置した場所はホンダワ

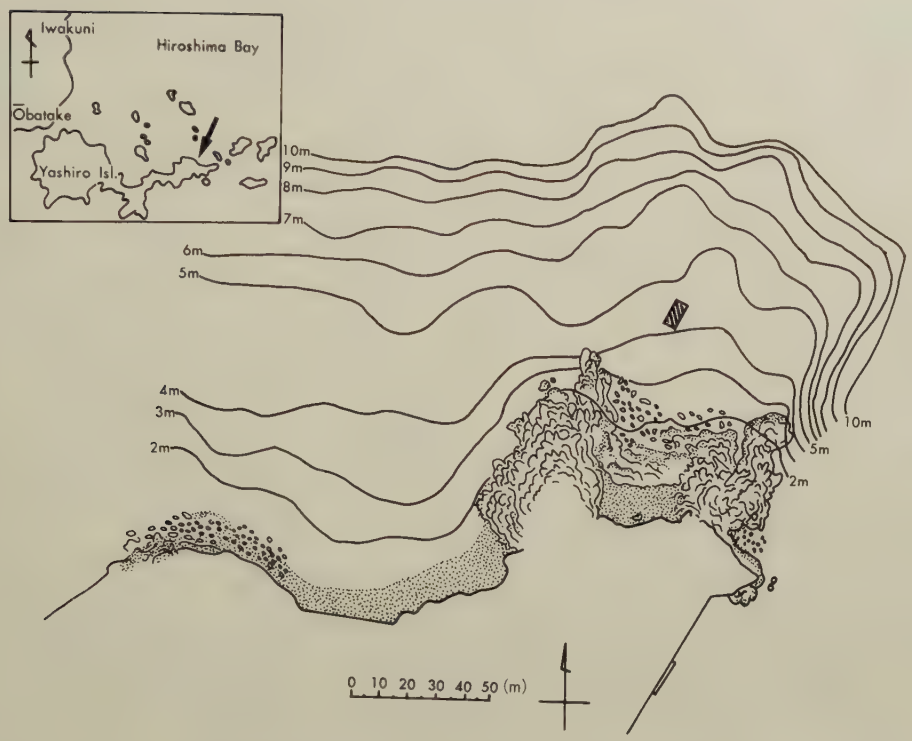

Fig. 1 A map of Matugahana Point, shouing the experimental site and depth countors. The Datum Level for Soundings of Towa town.....+1.760m

ラ群落の際の砂質帯で，水深は最干潮時2～3.5m の所である。流れは潮流による東西の流れが主で，その流速は最大60cm/sec 前後になる。

なお，生育環境として漁業者委託により，調査海域に近い東和町伊保田港内の9時の表層水温を観測した（Fig. 3）。

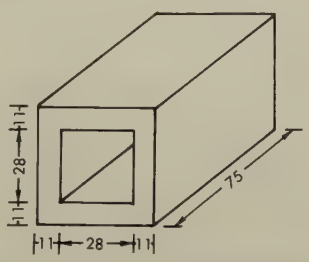

Fig. 2 Tipe of artificial reefs placed and studied in the sea. Units : cm

結　　果

1. 生長について

ヤツマタモクの最大主枝長および湿重量の変化は Fig. 3 に示した。

藻礁投入後約3ケ月を経た9月13日にヤツマタモクが着生し，3～4ケの主枝が形成されていた。

主枝は扁圧し，先端部がやや叉状となり，淡黄褐色を呈していた。この時の平均主枝長は6.3cmで，平均湿重量は0.23g であった。

12月1日にはヤツマタモクの伸長は著しく根も発達して多数の気胞を有して明らかに成体とな

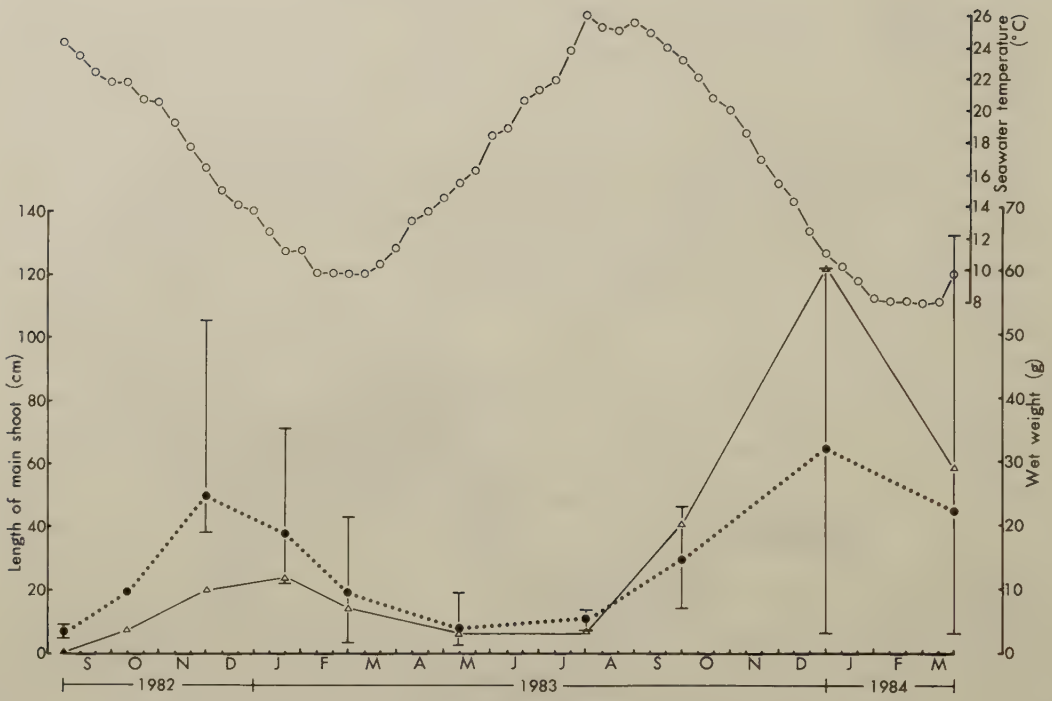

Fig. 3　The growth of *Sargassum patens*, 1982–1984.
—●—　The mean and the range of main shoots
△　The meaan wet weight
○　Chenge of ten days temperature of surface water at a fishery harbor near Matugahana Point

っていた。この間で，最も伸長した葉体は主枝長105cm，湿重量33.3g に達した。

その後，生長はみられず５月18日までの間は，最大主枝長は3.5～71.0cm，湿重量は0.2―36.0g の範囲で推移した。葉体は数本の主枝で形成されるが主枝間の差がひどく，必ずしも 一様の長さではない。さらには，ほとんどの葉体で主枝の先端が流失した跡がみられた。

５月18日には，葉体のほとんどは流失していたが，残存した基部より新しい個体が発生し生長していた。全測定個体のうち主枝長５cm以下の新生個体が占める割合は42%であった。

８月調査時には主枝長は7.0～13.5cm，湿重量は1.3～7.5g で平均した群を形成した。

10月３日調査時には，葉体の伸長が進んで主枝長は14.0～46.0cm，湿重量は0.5～54.8g の範囲にあった。ここでは伸長の良好なものとやや遅れた葉体群が形成されているが，これは残存個体と新生個体の生長差によるものである。

1984年１月７日調査時には生長が急速に進んで，最も伸長した葉体は主枝長121cm，湿重量196.0g であった。平均主枝長は64.2cm，平均湿重量は60.5g となり，２年目の生長としては最大に達した。

３月21日調査時には，主枝長131cm の葉体が１個体出現したが，その他の葉体は主枝長2.0～67.0cmの範囲であった。平均主枝長は44.5cm，平均湿重量は29.0g となり，１月７日調査時の値に比べていづれも小さい。

標識個体の測定結果については Fig. 4 に示した。20個体に標識を付けたが，脱落がひどく3個体しか追跡調査ができなかった。

標識個体の生長は個体 No. 153 は良く，坪刈調査の結果とほぼ同様であったが，個体 No.111 と No. 158 の伸長は緩慢であった。しかし，1月までは生長し，その後は生長が鈍化する傾向は明らかであった。

なお，個体 No.153 の日間生長率を求めると，10月12日～5月19日の間で3.9mm/日という値が得られた。

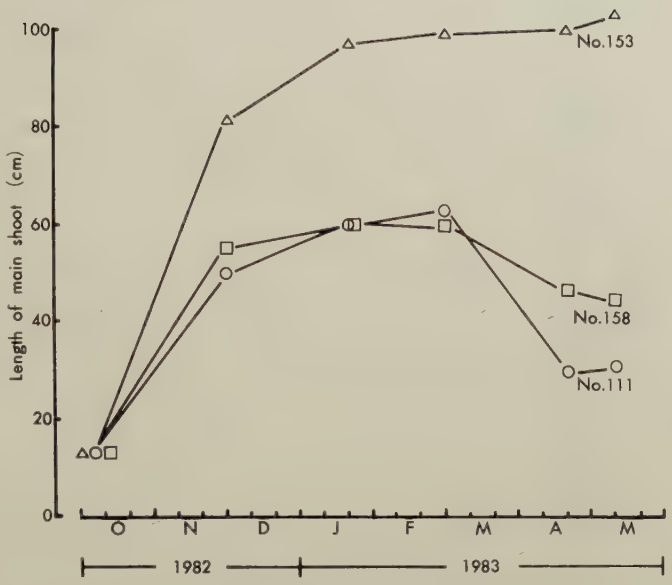

Fig. 4 The growth of tagged *S. patens*
No. 153, 158 and No. 111 are samples number

2. 生育密度と湿重量の変化について

坪刈調査で得られたホンダワラ類の生育密度と生育湿重量を Fig. 5, 6 に示した。

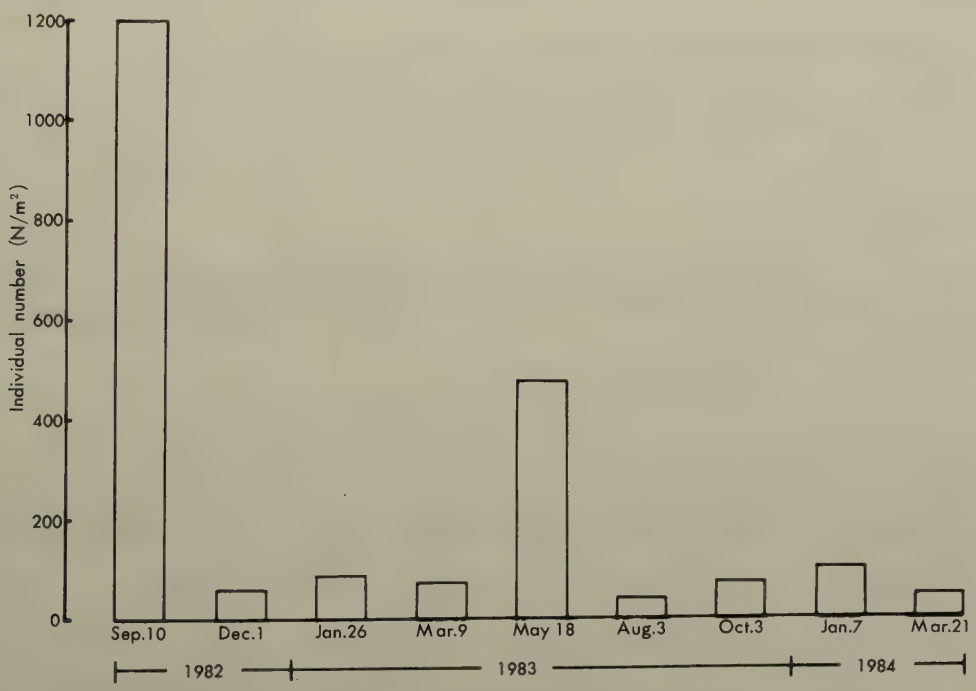

Fig. 5 Seasonal change of *S. patens* population in individual numbers

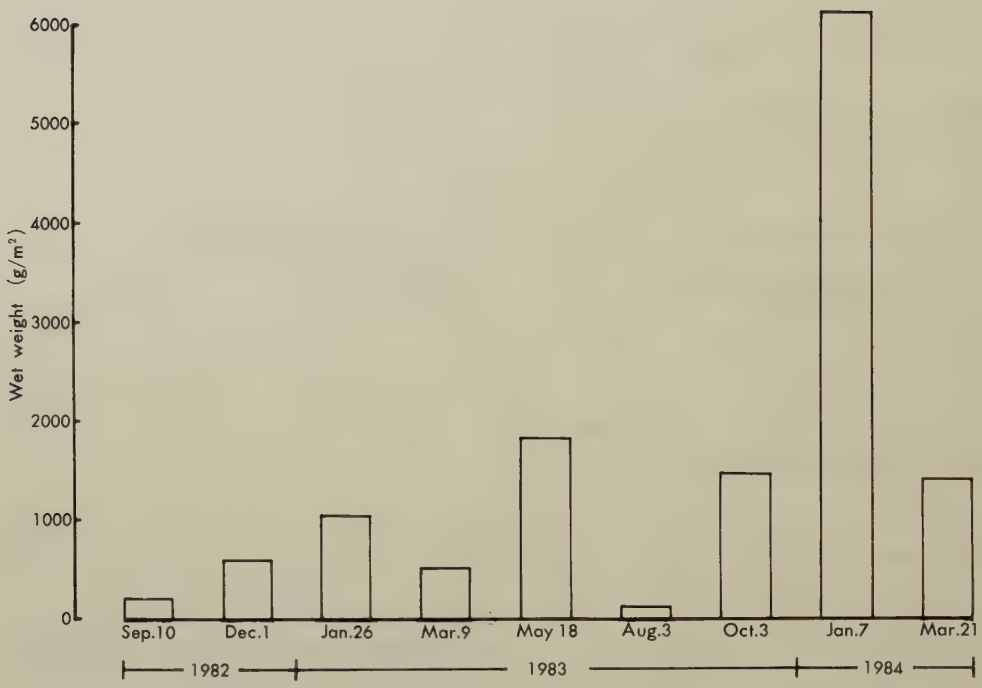

Fig. 6　Seasonal change of *S. patens* pooulation in wet weight

ヤツマタモクの親藻を1982年５月31日に藻礁へ固定したが，約３ケ月を経た９月10日には1200個体/㎡の幼体の着生を確認した。(Fig 5) しかし，その後急激に減少し，12月１日の調査では60個体/㎡までになっていた。その後は大きな変化はないが，1983年５月18日の調査では新生個体の着生がみられ急激に増加して475個体/㎡となった。

湿重量でみると９月10日には274g/㎡であったが，その後生長とともに増加し，２年目の1984年１月21日には6,050.0g/㎡までになった。(Fig. 6)

3.　成熟について

ヤツマタモクの生殖器床は１年目の個体にも２年目の個体にも観察されなかった。ただ１，２年目の３月の調査で生殖器床の形成前に主枝先端部が淡黄になる現象は多くの個体で観察された。

考　　察

ヤツマタモクは親藻投入後，卵が放出され，幼胚が落下して着生し，その後生長を続ける。３月以降生長は止まり，主枝の先端から枯死流失が始まる。そして，５月頃から残存した根より新生個体が萌出し，２年目の生長へ続く。このように新しい個体は５月頃に観察され，その生長のピークは12月から１月にかけてであった。

着生後の初期減耗については，生育密度から単純に計算すると，９月10日から12月１日の間の減耗率は95%とかなり高い値を示す。中久 (1980)，山本 (1981) らもヤツマタモクの人工種苗

を用いた養成試験の中で，幼胚および幼体の減耗が激しいと報告しているので，この時期の減耗は大きいと推定される。しかし，主枝長10cm以上の成体となったヤツマタモクの減耗は小さく，標識個体の追跡結果でみると，10月12日から5月19日までの約7ヶ月間に70%となる。

次に生育密度についてみると湿重量は132.8～6,050.0g/m²と変動が極めて大きい。最大生育湿重量は1年目では5月に1,817.5g/m²，2年目では1月に6,050.0g/m²を示し，量および時期とも顕著な差が生じている。

著者（1982），谷口ら（1978）の生態調査の中で，ヤツマタモクの最大湿重量は，前者が4月に4,022.8g/m²，後者が12月に3,032g/m²を示したとの報告と比べてみると本研究で得られた数値は大きい。しかし，湿重量が最大となる時期は場所や年度によってかなり異っている。湿重量の値が大きいのは，人為的にヤツマタモクを繁茂させたことで安定した群落が形成されたためと考えられる。

当地におけるヤツマタモクは水温が20℃以下に降下すると，伸長し始め，湿重量も増加する傾向にあり，しかも低水温の期間が長く続くと藻体の流失も少なく，生長も持続する。ヤツマタモクの生長には水温の影響が極めて大きく，その結果，湿重量の多寡および時期の違いとなって表われたものと考えられる。

また，湿重量は1年目に比べて2年目のそれはかなり大きい。これは2年目になると葉体枯死後に残存する基部より，少なくとも数本の新生個体が萠出し，9～10月頃より急速に伸長するためである。いいかえれば幼体から成体に至るまでの期間が1年目に比べて短期間ですむことになる。再生長による湿重量の増加は多年生藻体の極だつ特徴と考えられる。

次に，藻礁上のホンダワラ類種組成結果（Table 1）を天然藻場の坪刈結果（Table 2）と比

Table 1. Standing crops of *Sargassum* spp. in the artificial *Sargassum* beds, 1982–1984.

Species \ Date	Sep. 10		Dec. 1		Jan. 26		Mar. 9		May 18		Aug. 3		Oct. 3		Jan. 7		Mar. 21	
	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²
Cystophyllum sisymbrioides															20	43.0		
S. patens	1200	274.0	60	600.0	87.5	1048.8	72	503.6	475	1817.5	40	132.8	72	1450.4	100	6050.0	48	1389.6
S. horneri	1300	175.0	10	248.0			28	687.6	25	87.5			16	1.6	20	1816.0		
S. tortile											8	78.4	24	44.8			8	82.4
S. muticum			10	37.0					25	50.0							8	201.6
S. micracanthum											8	224.0			50	1087.0		
Sargassum spp.											16	12.0						
Total	2500	449.0	80	885.0	87.5	1048.8	100	1191.2	525	1955.0	72	447.2	112	1496.8	190	8996.0	64	1673.6

N/m²…Individual in I m²　g/m²…Wet weight in I m²

Table 2. Standing crops of *Sargassum* spp. in the natural *Sargassum* beds at Matugahana Point, 1982–1984.

Species \ Date	Sep. 10		Dec. 1		Mar. 9		May 18		Aug. 3		Oct. 3		Dec. 22		Mar. 21	
	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²	N/m²	g/m²
Cystophyllum sisymbrioides	4.5	213.9	8.5	644.2	7.5	146.8	13	1219.0	10	94.6	13	1601.0	11	2522.1	6	671.0
S. patens	5	24.8	5	87.1	3.5	98.2	1	2.0	1	11.5	23	462.4	3	27.8	7	172.1
S. horneri	107.5	29.6	93	1959.3	54	2796.6	32	938.1	2	0.8	25	13.1	5	497.2	18	1290.6
S. tortile	10	118.2	3.5	58.9	1	54.5	5	115.5	5	222.8	5	208.5	6	1567.4	9	542.5
S. muticum					3	22.0					40	24.2	3	3.7		
S. micracanthum	3	122.6	4.5	85.1	4.5	16.8	2	479.0	7	296.0	27	10.3	5	4.5	3	5.3
Sargassum spp.	8	105.6	22	998.0	5.5	324.0	5	34.0	10	36.3	20	569.5	5	2255.0	2	1303.0
Total	138	614.7	136.5	3822.6	79	3458.9	58	2787.6	35	662.0	153	2889.0	38	6877.7	45	3984.5

N/m²…Individual in I m²　g/m²…Wet weight in I m²

較すると，明らかに藻礁上の種組成は単純であった。これはヤツマタモク親藻投入により，確実にその幼胚が基質に着生したことによると考えられる。出現したホンダワラは６種で，各調査毎にはこれらのうち１～３種が混生するものの常在種はない。このように藻礁上にもアカモクなど他のホンダワラが混生するのは，藻礁の設置点が既存藻場の際であることから，卵が流れ着くのと，放出時期が一致したためと考えられた。

藻礁上に着生したホンダワラ類は，１年目ではヤツマタモクの単一群落であったが，２年目ではヤツマタモク優占のホンダワラ類混生群落に変った。しかし，群落は衰退することなく順調に推移していた。

ヤツマタモクの成熟は晩春から初夏といわれている（猪野1947，谷口ら1978，吉田ら1975)。しかし，今回の調査では確認されなかった。これは，1983年，1984年の冬が異常に寒かったことによる水温低下や，風浪のため成熟直前の個体が流失したことも一原因と推定された。しかしながら，主枝先端部の褪色現象や，夏期における新生個体の出現などから成熟時期は３～６月と考えられる。

今回の藻場造成に用いたのり網によるヤツマタモク親藻被覆はその後の群落形成過程から推測すると成熟親藻の流失を防ぎ，また，幼胚の拡散を少なくすることができるので，流れの比較的速い海域や，単一優占群落藻場の造成には有効な方法と考えられた。

要　　約

山口県大島郡東和町伊保田松ヶ鼻地先において，既存藻場周辺に人工基質を設置し，ヤツマタモクの親藻をのり網で被覆する方法で造成試験を行った。

その結果，以下の知見を得た。

1．藻礁投入後約３ケ月を経た９月13日にヤツマタモクは着生し，その後は緩やかな生長を続けた。３～５月にかけて，主枝は根部を残して枯死・流失した。そして５月頃には残存した根部より新生個体が萌出するが，それらは，10～１月の間では急速に生長した。３月になると，ほとんどの藻体で主枝の先端が流失し始め，１年目と同様な現象が観察された。

2．ヤツマタモクは造成藻礁に優占群落を形成した。その最大現存量は1984年１月７日に，100個体/m²・6,050.0g/m² に達した。

3．ヤツマタモクの群落形成は，１年目が割合緩慢に進んだのに対して，２年目では残存根の再生長による新生個体の発生や，その伸長が著しいことも加わってかなり速いことが明らかとなった。

4．標識個体の追跡調査から，1982年10月12日～1983年５月19日の約７ケ月間における最大日間生長率は3.9㎜/日となった。また，残存率は約30％と推定された。

5．造成藻礁上のヤツマタモクの成熟時期は確認できなかったが，主枝部の褪色現象や新生個体の出現状況から３～６月と推定された。

6．この研究で用いたのり網による親藻被覆方法は，親藻の流失防止には効果的と考えられる。

したがって，比較的流れの速い海域や，単一優占群落藻場を造成する場合には有効であろう。

文　　献

猪野俊平，1947：海藻の発生，北隆館，東京，50—53.

中久喜昭，1980：ホンダワラ類の種苗生産研究　Ⅲ，培養中の幼胚，幼体の減耗，徳島県水産試験場事業報告，118—120.

南西海区水産研究所，1981：有用海藻群落，近海漁業資源の家魚化システムの開発に関する総合研究（マリーンランチング計画），昭和55年度研究成績報告書，41—104.

南西海区水産研究所，1982：有用海藻群落，近海漁業資源の家魚化システムの開発に関する総合研究（マリーンランチング計画），昭和56年度研究成績報告書，31—99.

南西海区水産研究所，1983：有用海藻群落，近海漁業資源の家魚化システムの開発に関する総合研究（マリーンランチング計画），昭和57年度研究成績報告書，39—127.

谷口和也・山田悦正，1978：能登飯田湾における褐藻ヤツマタモクとノコギリモクの生態，日本海区水産研究所報告，（29），239—253.

山本　翠，1981：ヤツマタモクの人工種苗生産試験（昭和53，54年度），山口県内海水産試験場研究報告書，136—144.

吉田範秋・西川　博，1975：ホンダワラ類の生長，長崎県水産試験場研究報，（1），13—18.

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Bull. Nansei Reg. Fish. Res. Lab. No. 18, 1985

周防灘におけるサワラの分布と回遊

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原　健一[*3]・桧山節久[*3]・上田和夫

Distribution and Migration of Japanese Spanish Mackerel in the Sea of Suō

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Distribution and migration of Japanese Spanish Mackerel, *Scomberomorus niphonius*, in the Sea of Suō were investigated from August 1981 to December 1983. The semi-monthly CPUE distribution was examined. Catch and fishing effort data were obtained from several commercial fishing boats operating drift gill nets in the Sea of Suō and the adjacent eastern part of the Sea of Iyo.

Migrations from the Sea of Iyo to the investigated area were observed twice a year.

The first migration occurred from the latter half of May to the first half of July. This migration consisted of spawning adults.

The second migration began during the latter half of September and the first half of October, and ended in December due to a drop in the water temperature.

Water temperatures of the area where fish distributed at a depth of ten meters were approximately between 15 and 22°C, and between 13 and 24°C in the respective migratory seasons.

The September-December migration was about six times as abundant in numbers as the May-July migration.

瀬戸内海西部の周防灘ではサワラ *Scomberomorus niphonius* (CUVIER) は流し刺網，小型定置網等の漁獲対象となり，1978～82年の5年間では年間154～432トン，平均271トンの水揚げがあった（中四国農政局1980～1984）。この水揚量のうち91.4%は流し刺網によるものであったが，これの上記5年間の月別漁獲量は9～12月（以下秋漁期）にほとんどが集中している。しかし，1981，82年には5～7月（以下春漁期）にも漁獲量の山がみられた。このように月別漁獲量が季節的に大きく変動するのは周防灘へのサワラの来遊構造に起因するものと考えられている。

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瀬戸内海中西部域と豊後水道におけるサワラの回遊については，小中（1961），能津（1967），工藤（1968，1978，1982）や灘別・月別漁獲量統計からおよそ次のように推測される。すなわち，5・6月の産卵期には燧灘・安芸灘へ回遊し，8月前後には別府湾々口部付近以外の水域から姿を消すものの，秋には伊予灘，周防灘へ回遊し，冬には多くが豊後水道へ南下するものとみられる。

しかし詳細な点については不明なことが多く，周防灘においてもサワラの回遊，海洋環境との関係などの知見は極めて少ない。

著者らは今回周防灘及び隣接海域において，サワラ流し刺網の当業船を用いた漁場調査を行い，回遊に伴う分布域の特性と水温との関係，並びに時期別来遊量の相対指数による検討などを行ったので報告する。

本報告をとりまとめるに当り，忙しいなか操業日誌をつけて頂いた漁業者の方々に対し厚くお礼申し上げる。また，本論文の校閲を賜わった内海資源部尾形哲男部長，終始多大な協力を頂いた内海資源部高尾亀次主任研究官に対し深謝の意を表する。

なお本研究には，「海洋生物資源の生産能力と海洋環境に関する研究」（科学技術庁）で得た資料を併用したことを付記する。

方　　法

周防灘沿岸及びその周辺でサワラ流し刺網に出漁している地区を適当な間隔を置いて選び，そ

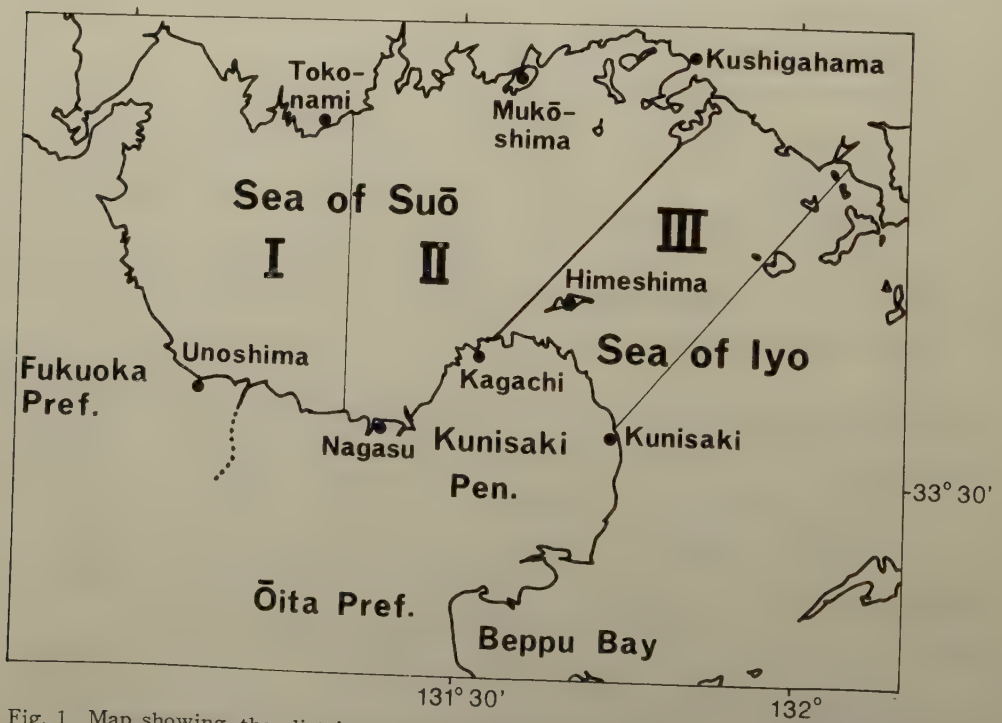

Fig. 1　Map showing the districts where sample boats were set. The arbitrary partitions of sub-area (I–III) in investigated area are also shown.

れらの地区に1隻ずつ当業船による標本船を配置した。標本船には操業日誌の記帳を依頼したが，記帳項目は出漁日ごとの操業時間，操業位置，サワラの銘柄別漁獲尾数などとした。

標本船設置地区は，大分県の東国東郡国東及び姫島，西国東郡香々地，宇佐市長洲，福岡県豊前市宇島，山口県宇部市床波，防府市向島，徳山市櫛ヶ浜とした（Fig. 1）。但し，宇島では1982，83年には標本船を2隻とした。

標本船の設置期間は1981年8月から1983年12月までの間の漁期としたが，地区によっては設置が遅れたり，都合により途中で打ち切ったりした場合があった。各地区標本船の出漁した月，日数は後掲の Fig. 2～9に示す。

各標本船が用いた刺網は，船によって若干差がみられ，長さの範囲は1,500～2,520m，目合の範囲は10.2～10.9cm（大部分が10.6cm）であった。

なお，今回の調査に用いた標本船はサゴシ（秋漁期には当才，春漁期にはほぼ満1歳までのものをいう）を漁獲対象としていないため，サゴシ期の分布については扱えなかった。したがって本報告で対象としたのは，秋漁期は1歳の未成魚と2歳以上の成魚，春漁期は2歳以上の成魚である。

結果と考察

1. 分布域と水温の時期的変化

周防灘及び隣接海域を経緯度5分ます目の漁区に分け，漁群密度の指標として CPUE(C_i/X_i) を漁区別，半月別に求めた。ここで C_i は漁区 i における半月間の漁獲尾数（サゴシを除く），X_i は同じ期間中に漁区 i に投入された漁獲努力量である。漁獲努力量は，その期間中にその漁区で行われた全操業について用いられた刺網の長さ（km）を合計したものとした。サワラ流し刺網操業は夕刻に投網し翌日未明に揚網するのが一般的で，これを1操業とした。夜中に揚網して一晩に2回操業する場合もまれにあったが，この場合も合計で1操業とした。1回の操業が2つ以上の漁区にまたがって行われた時は，操業状況に応じて努力量及び漁獲量を関係漁区に比例配分した。

得られた半月別密度（CPUE）分布図を季節ごとに示すと Fig. 2～9 のようになる。また，当該期間中の標本船の出漁日数を，地区別に示した。さらに，各月前半の図にはその時期の水深10m層の等温線も合わせて示した。この等温線は大分，福岡，山口各県の浅海定線調査資料（未発表）をもとに描いたもので，水温の観測日を図中の括弧内に示す。

1.1 秋漁期前半

秋口の移入期から周防灘全域に分布する時期までの各年の密度分布図を Fig. 2～4 に示す。

8月は，1981年（Fig. 2）には国東にしか標本船を配置できなかったが，1982, 83年（Fig. 3, 4）の結果によると周防灘では漁獲は見られなかった。以下，標本船による漁獲の見られた漁区を漁場と呼ぶが，8月の漁場は別府湾々口部から国東半島南東部沖合に限られており，これは「

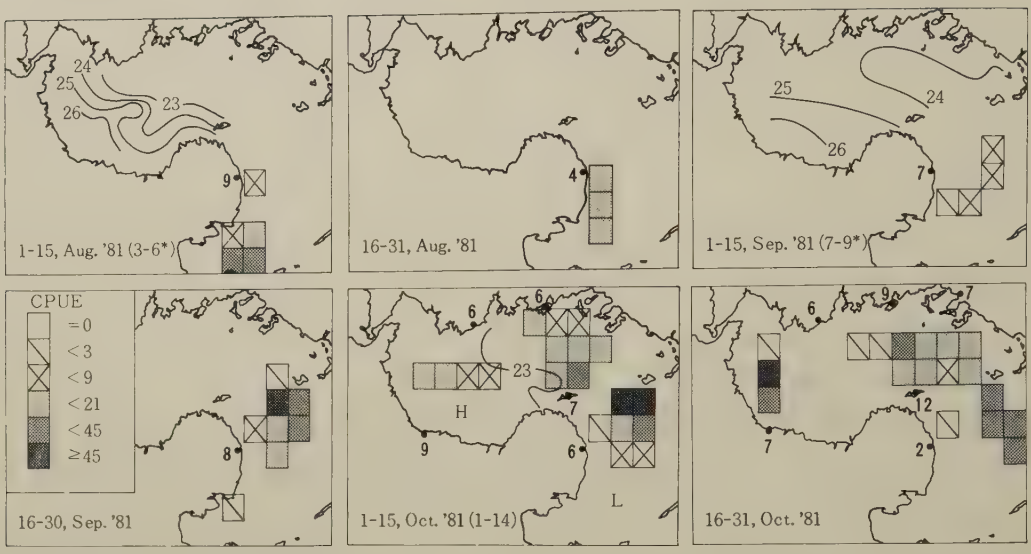

Fig. 2 Semimonthly distribution of CPUE by regions (5 minutes latitude by 5 minutes longitude). Black circle denotes the district from where the sample boats went out fishing. Each figure indicates the number of operations.

The isotherms (°C) at a depth of ten meters are based on the water temperatures taken during the period indicated in the parentheses. An asterisk (*) indicates that most of the data of water temperature in the Sea of Iyo were missing.

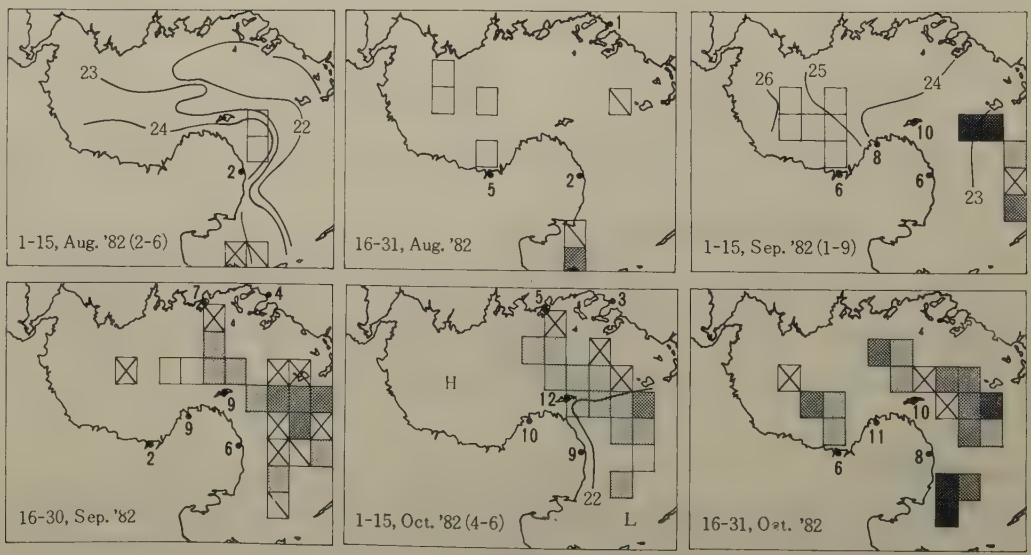

Fig. 3 Legend is the same as given for Fig. 2.

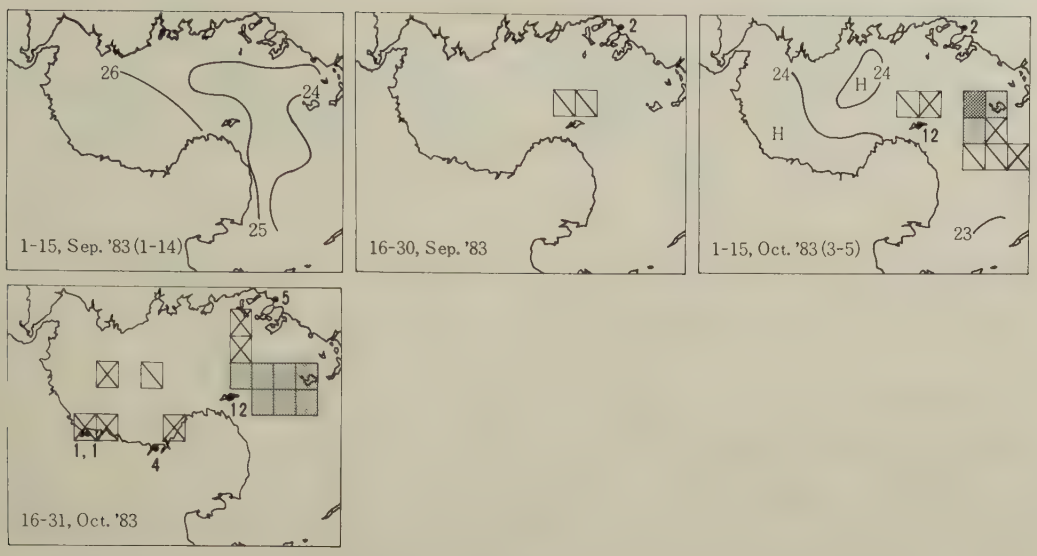

Fig. 4 Legend is the same as given for Fig. 2.
The number of operations in August was zero for all sample boats.

藤（1978, 1982）の報告と大体一致する。

9月も1981年（Fig. 2）は，国東の記録しか得られなかったが，後半には漁場が周防灘入口付近まで北上していた。1982年（Fig. 3）には9月前半の漁場は周防灘入口付近に達していた。このとき漁場の先端部の水温は約23℃で，周防灘は24℃以上であった。後半には漁場は周防灘中央部まで拡大した。1983年（Fig. 4）9月はほとんど漁が見られなかったが，この年は，1981, 82年に比べて水温が高く9月前半はほぼ周防灘全域で25℃以上であった。

以上のように9月は8月に比べ漁群が北上している様子がわかる。工藤（1982）によれば別府湾付近では体重2～3 kgのサワラが9月前半頃までとれ，その後は700～800gのサゴシが大部分になるという。このことからもサワラは9月には8月の漁場から他に移動することがうかがえる。

10月は，1981年（Fig. 2）の場合，月前半に周防灘西部まで漁群が達していた。この時期の水温は西部で23℃台，東部で22℃台であった。1982年（Fig. 3）10月前半の水温は全域で22℃台であったが，魚場は東部にしか見られず，9月後半と比べて漁場の拡大は見られなかった。この月，周防灘西部地区の標本船は出漁しなかったが，このような場合，普通はその海域の CPUE が採算に合わない程小さいためであろうと解釈されるが，CPUE がある程度大きくなっても，他の漁業が好調であった等の理由でサワラ流し刺網への転換が遅れる場合も考える必要がある。前者の場合未知の漁区の CPUE はほとんど0とみなして差し支えないであろうが，後者の場合標本船による操業海域は魚群の分布域に比べて小さくなり，分布範囲が過小に推定されることになる。1982年10月は前年の傾向と比較して後者の場合，すなわち何らかの理由でサワラ流し刺網への転換が遅れたのではないかとみられる。1983年（Fig. 4）は10月前半になっても水温が高く周防灘西部，中部で24℃台，東部で23℃台を示し，漁場の分布は周防灘入口付近までであった。

各年とも10月後半には，漁場は西部にまで拡大したが，1983年（Fig. 4）における密度の比較

的高い漁区は，周防灘内部にはまだ見られなかった。

以上のとおり標本船の漁場形成からみて，瀬戸内海中西部域のサワラの分布は８月には別府湾々口部及び国東半島南東部沖合以外ではほとんど認められていないが，秋になって水温が降下すると共にこの付近から北上し周防灘にも来遊する状況が把握された。分布域の10m層水温の上限は８月の分布域の縮小期を除くと23℃台であった。なお，小中（1961）は秋の豊後水道におけるサワラの南下は，23～24℃（表層）の内海系寒水帯の南下と同時であるとし，秋口に逆に豊後水道へ南下するサワラ群の存在を報告しているが，工藤(1968)は，その後この群が見られなくなったとしている。現在の状況は不明である。

1.2 秋漁期後半

11月以降の半月別密度分布図を Fig. 5～7 に示す。

11月には各年とも豊前海（福岡，大分県沖）の沿岸域まで来遊していることがわかる。1981年（Fig. 5）は1982，83年より早く，11月後半には西の方から移出が既に始まっていたようである。なお，1983年（Fig. 7）は周防灘東部地区の標本船配置が充分に行えなかったため，東部の様子は不明であった。

12月になると，1981年（Fig. 5）は周防灘西部地区の標本船が休漁したため西部の様子は不明であったが，漁場は中部以東に縮小し，その水温はほぼ 14℃ 以上であった。1982年12月前半（Fig. 6）は，豊前海の13℃以下の部分を除いてほぼ周防灘全域に分布が見られたが，密度が高い漁区は東へ移動していた。1983年12月（Fig. 7）は水温の降下が過去２年より早く，サワラの分布は12℃台の水域にも見られた。この年は秋口の高水温のために来遊が遅れたとみられるが，過去２年より水温の降下に伴う移出が遅れたのはこのことが影響しているのではないかと考えられる。周防灘東部の様子は11月同様不明であった。

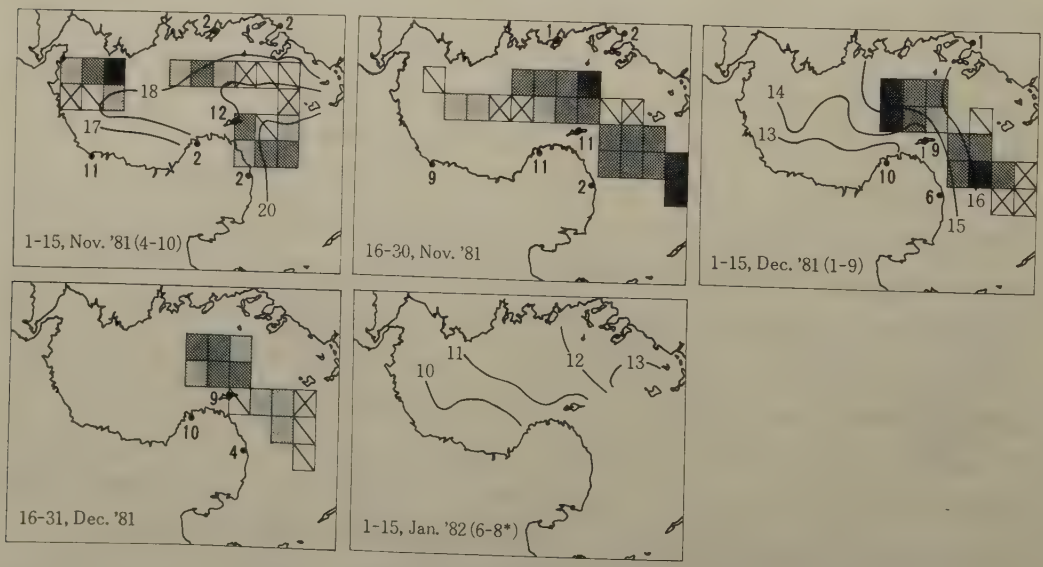

Fig. 5 Legend is the same as given for Fig. 2.

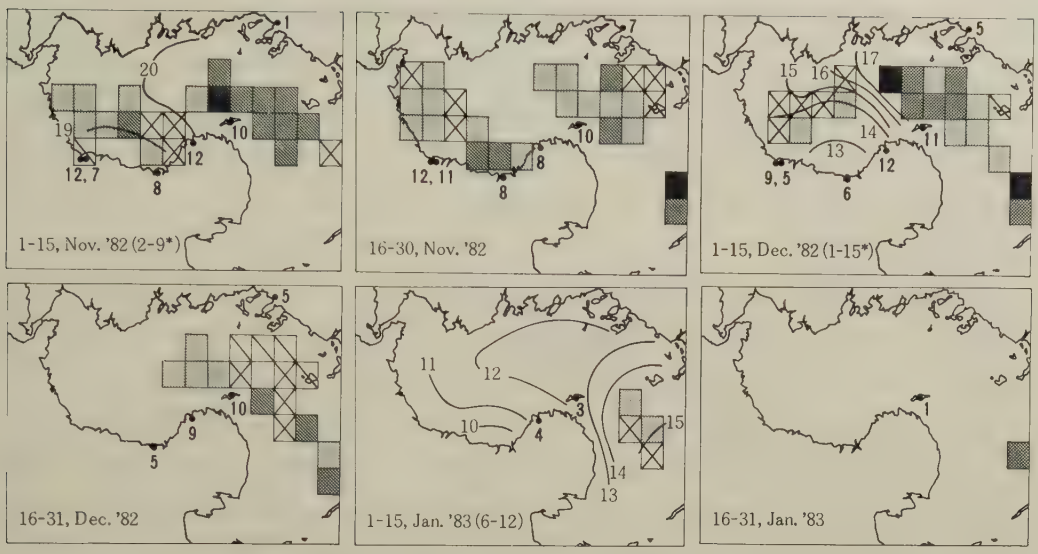

Fig. 6 Legend is the same as given for Fig. 2.

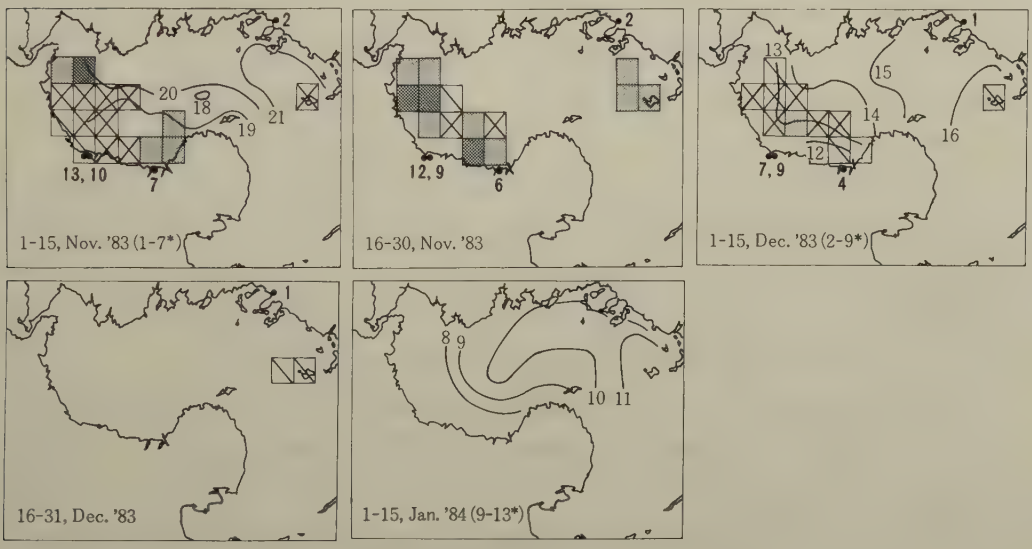

Fig. 7 Legend is the same as given for Fig. 2.

1月から春漁期が始まる5月までは各標本船のサワラ流し刺網は休漁状態となるが，1983年1月は，姫島，香々地のマナガツオ流し刺網（網の目合等はサワラを対象とする場合と同一のものを使用している）の結果から混獲されたサワラの漁場を見た（Fig. 6）。これによればサワラ漁場は1月前半には伊予灘に移っていた。漁場の水温は14℃以上であった。1月後半にはさらに南下し，伊予灘南部にわずかに見られただけであった。

1.3 秋漁期のまとめ

以上のように秋漁期の周防灘における漁場分布をみると，サワラの分布域は水温の分布構造と

深いかかわりがあるようにみられる。周防灘及び隣接の伊予灘西部では全般に西部の方が水温の年較差が大きく，伊予灘の方が小さい。つまり秋漁期における伊予灘から周防灘への移入期は低水温域から高水温域への回遊であるが，その上限は10m層水温で約24℃，また逆に移出期は低水温域から高水温域への回遊であるが，その下限はおよそ12～13℃と考えられる。小中（1961）は豊後水道における秋から冬のサワラ漁場の表面水温は14～23℃であるとしており，今回の結果とほぼ一致する。

一方，岩井・森脇* が瀬戸内海東部の播磨灘及び大阪湾でサワラ流し刺網の試験操業を行った結果では，8月下旬から9月上旬の，水温がおよそ26～27℃（水深10，20m）の頃からサワラが漁獲されており，サワラの分布水温は海域によって若干差があることを示唆している。

なお，日誌に記された漁獲物の銘柄分けは目分量で行われたため正確とは言えないが，一応の目安として秋漁期の標本船による全漁獲物の銘柄組成をみた。その結果，小（およそ1.5～2.4kg）が70%を占めていた。サワラの成長（岸田・他未発表）から考えて銘柄が小に分類されたものの多くはサワラ流し刺網に対する新規加入群（1歳）と考えられた。

ところで，秋漁の最盛期には漁場の形成状況からみて回遊群は，豊前海のごく沿岸域まで回遊する群と，周防灘東部の比較的沖合に滞留する群の2つに分かれている観がある。しかし，この現象については，単に標本船の操業範囲の偏りによる見かけ上の現象なのか，あるいは2つの群が年齢構成などを異にする異質の集団であるのか，あるいは同質でも餌料生物の分布特性などといった環境要因によって2分されているのか，今回は十分な資料がなく検討し得なかった。

なお，周防灘は関門海峡によって日本海とつながっているが，漁場の推移からみて周防灘に来遊するサワラは日本海のものとは別の群とみられる。

1.4 春漁期

5～7月の半月別密度（CPUE）分布図を Fig. 8～9 に示す。

この時期はサワラの産卵期であり瀬戸内海中西部では燧灘，安芸灘でサワラ卵稚仔の分布が知られている（岸田1983）。周防灘へこの時期に来遊するサワラの大きさは日誌に記された目測による銘柄組成でみると，小（およそ1.5～2.4kg）37%，中（およそ2.5～3.4kg）46%，大（およそ3.5kg以上）17%となっており，いずれも産卵群，すなわち2歳以上（岸田・他未発表）と考えられる。

図をみると，1982，83年とも周防灘へは5月後半に移入を開始し，6月前半から7月前半にかけて周防灘中央部付近まで回遊していることがわかる。但し，周防灘西部に位置する福岡県豊前市沖でも，1982年5月下旬，6月上旬に小型定置網（沖桝網）でサワラ成魚が合計で10尾以上（体重1.7～4.1kg）漁獲されているのを著者らが確認しており，春漁期の来遊範囲についてはさらに詳しい調査が必要である。なお，豊前市宇島の標本船はこの時期は別の漁業に従事しており，サワラ流し刺網には出漁していなかった。

周防灘における春の回遊期の分布水温はおよそ15℃～22℃であった。7月後半の移出時期は比

* 岩井昌三・森脇胖二：昭和42年度～昭和43年度兵庫県立水産試験場報告，昭和44年度～昭和51年度兵庫県立水産試験場事業報告。

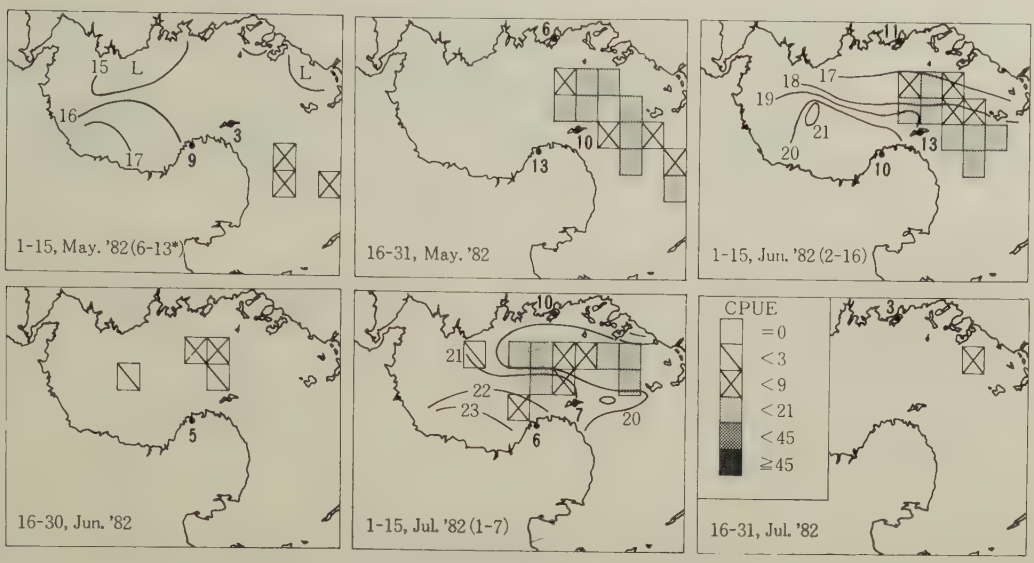

Fig. 8 Legend is the same as given for Fig. 2.

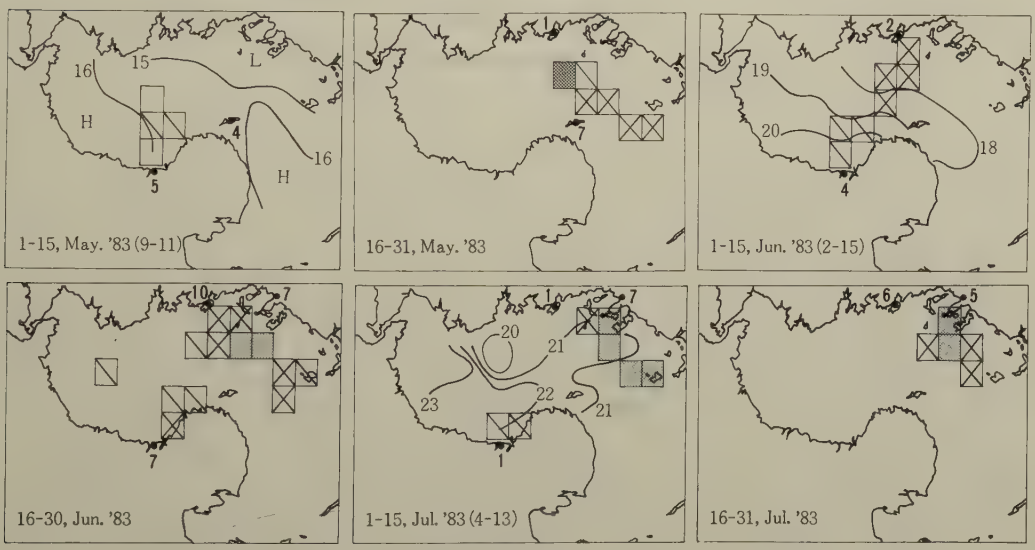

Fig. 9 Legend is the same as given for Fig. 2.

較的低温の山口県側に分布が偏るようである。

なお，山口・福岡・大分県（1975）によれば，周防灘の塩分は６～８月頃に降雨の影響で最低となり，冬季に高い。そして地域的には全般に東高西低であるという。春漁期のサワラが周防灘中央部より西へあまり回遊しないのはこの時期の塩分低下によるためかとも考えられるが，1982年の塩分（既出の浅海定線調査資料）を見ると（Fig. 10），周防灘全域にサワラの分布が見られた11月より６，７月の方が高塩分となっており，必ずしも低塩分に原因を求めることはできない。

なお，月別漁獲統計資料が利用できる1978～1982年について，周防灘におけるサワラ流し刺網の月別漁獲量（中四国農政局1980～1984）を Fig. 11 に示す。1978～80年には春漁期（５～７月）

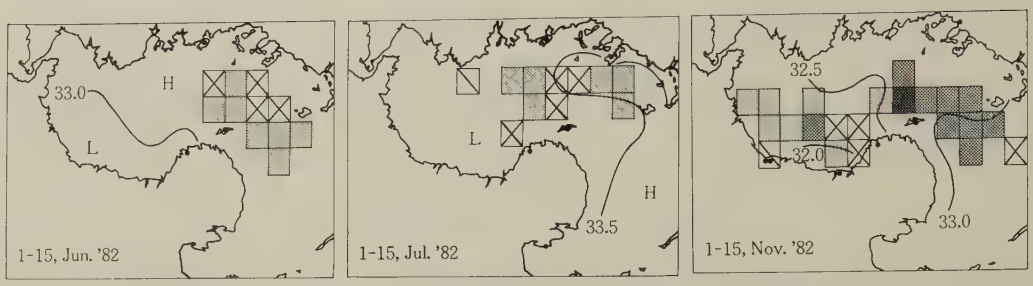

Fig. 10 Distribution of salinity (‰) at a depth of ten meters and CPUE in the first half of June, July and November, 1982.

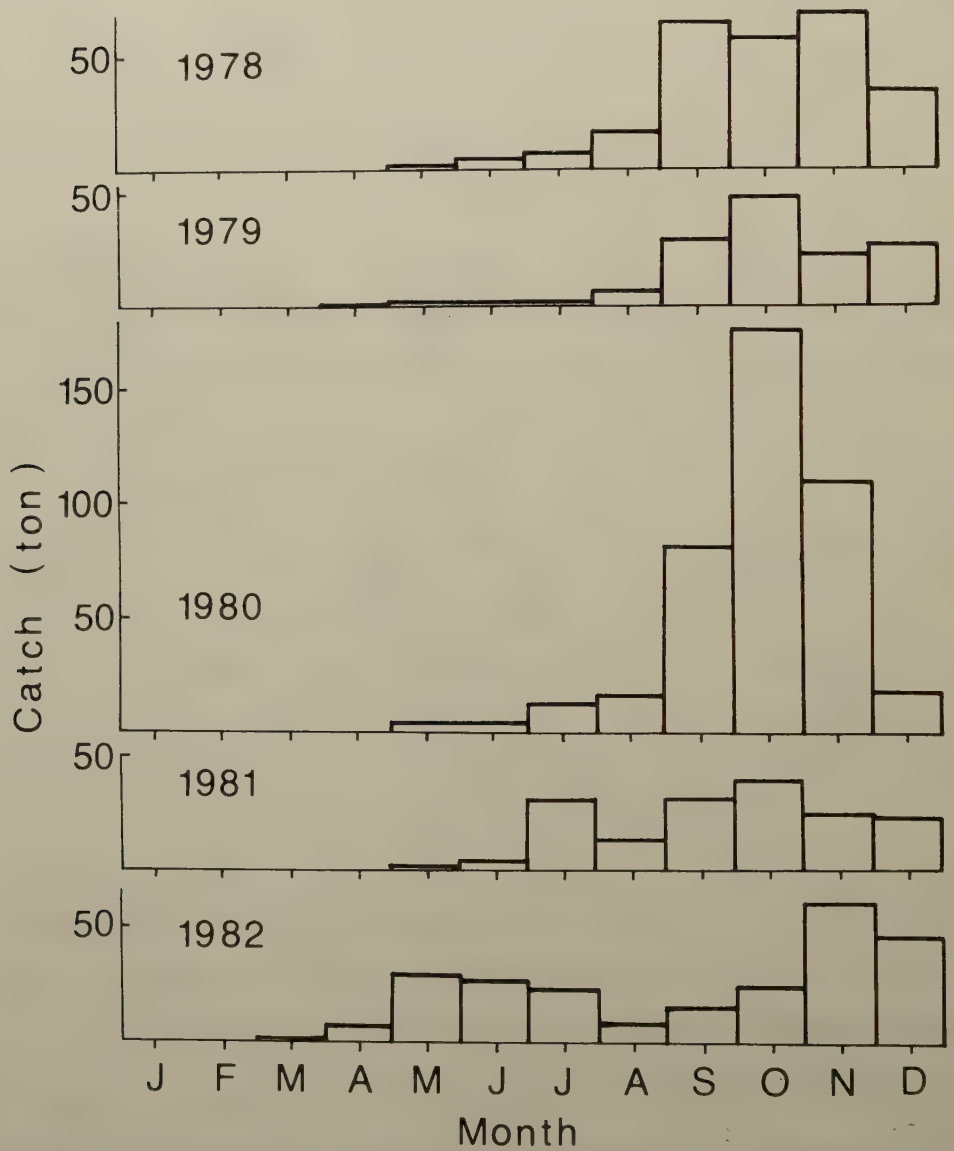

Fig. 11 Monthly catch of Japanese Spanish mackerel by drift gill net from the Sea of Suō, 1978–82.

の水揚げはほとんど無く，1981年以降増大傾向に転じている。漁獲量がその水域の魚群量をある程度反映しているとすれば，図から1978～80年の間，周防灘への産卵群の回遊はほとんど無かったといえる。1981年以降の増大傾向については，時期的な対応からみて海洋環境の変化，特に1980年夏の黒潮大蛇行の消滅に伴う豊後水道への黒潮分枝流の動態（藤本1984）との関連が一応注目されるが，この問題については今のところ立ち入って言及する段階に至っていない。

2. 相対指数からみた時期別来遊量

周防灘及び隣接海域を Fig. 1 に示すとおり周防灘西部（Ⅰ），東部（Ⅱ），及び隣接海域（Ⅲ）の3海域に区分し，各海域への来遊量の相対指数を田中（1957）の資源量指数によって求めた。ここではこれを現存量指数 P と呼ぶ。P は以下の式で与えられる。

$$P=\Sigma A_i(C_i/X_i)$$

ここで A_i は漁区 i の面積*，C_i（漁獲尾数），X_i（漁獲努力量）は既出のものと同じである。但し，期間の区切りをここでは旬（10日）とした。

なお，現存量の増減以外の要因及び標本誤差等による変動を考慮し，ここでは三項単純移動平均によって旬別の値を求め，結果を Fig. 12 に示した。但し一連の漁期の両端の値はそのまま用いた。

標本船の出漁隻数が不充分で，その操業範囲が来遊群の分布域全体を被えなかったと考えられるような場合，現存量指数 P も当然過小推定になる。また，三項単純移動平均で表わしているためピーク時の値も単純には比較できないであろう。したがって正確な比較はできないが，一応 Fig. 12 によって魚群の来遊状況を概観した。これによれば1981，82両年秋漁期の周防灘への来遊量の水準はほとんど同じであったとみられる。周防灘入口の海域Ⅲまで含めた場合の来遊量は'82年の方が'81年より約2割上回っているが，秋漁期の後半をみると'81年の方が海域Ⅱ，Ⅲで遅くまで高い指数が得られている。つまり魚群が遅くまで残留していたものと推察できる。

1983年は，'81，82年に比べ9，10月の周防灘の指数は極めて小さい。これは'83年のこの時期が高水温で魚群の来遊が少なかったことと，標本船配置数が少なかったことが影響していると考えられる。11月以降の海域Ⅱ，Ⅲについては標本船数がさらに減ったため指数の算出は行わなかった。西部の海域Ⅰは，時期的には遅れたものの，来遊量は'81年とほぼ同水準であったとみられる。

春漁期は秋に比べて量的には1／6程度となっているが，'82，83年とも同水準の来遊が認められている。海域Ⅲについては'82年と'83年の間で来遊量，時期ともに若干の差があり，'82年には5月中旬に来遊のピークがあり，量的にも高い値が得られた。'83年には6月上旬頃に来遊のピークがあらわれている。海域Ⅰへの春期の来遊は既に述べたとおり，'82，83年ともにほとんど見られなかった。

＊ 南西海区水産研究所内海資源部資料（未発表）による。

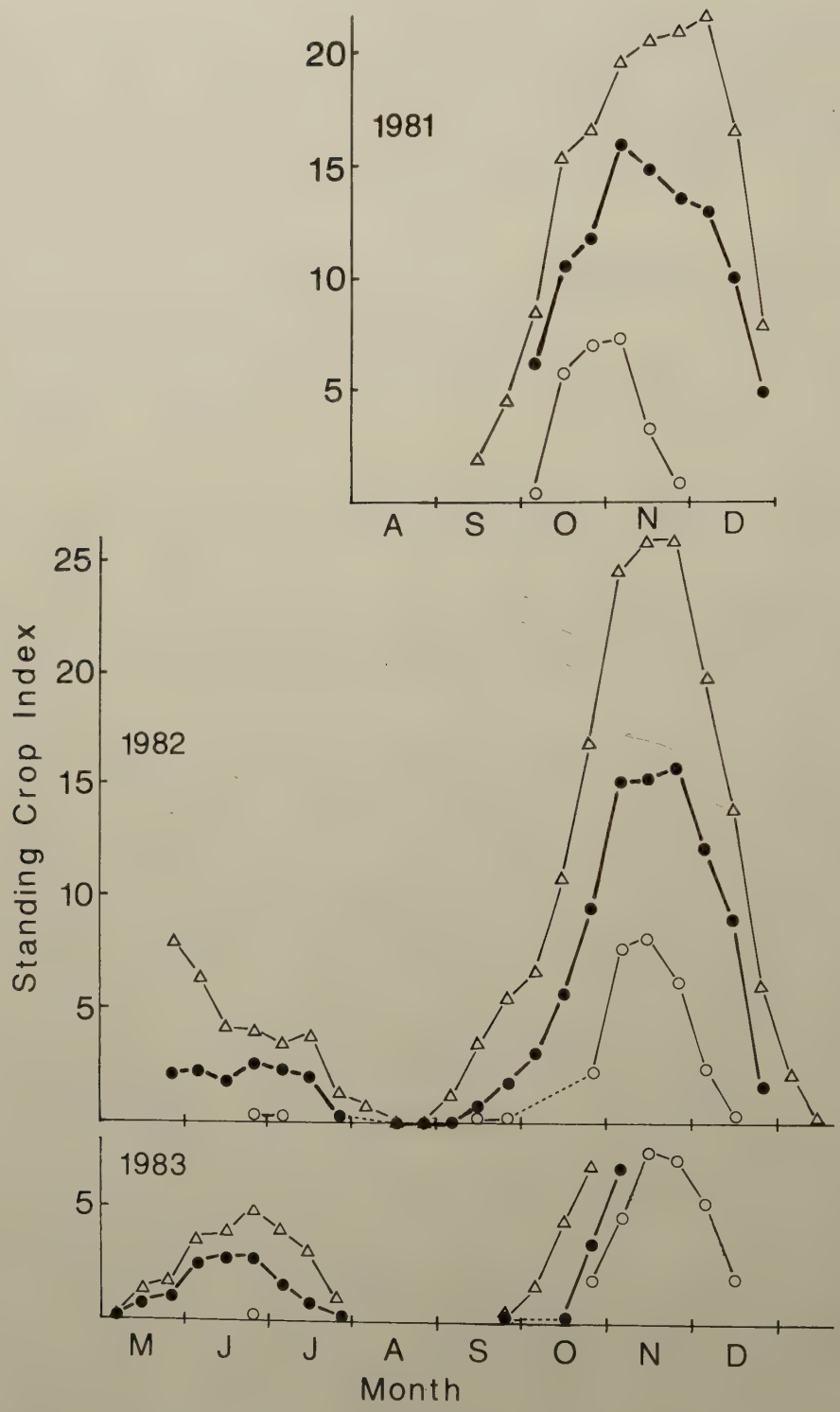

Fig. 12 Standing crop index of sub-area based on numbers of fish for each period of ten days.
White circle: sub-area I (see Fig. 1). Black circle: sub-areas I and II (viz. Sea of Suō). Triangle: sub-areas I, II and III.

摘　　要

1981年８月から1983年12月にかけて，標本船日誌により周防灘及び隣接の伊予灘西部におけるサワラの分布と回遊を検討し，以下の知見を得た。

1．周防灘へサワラが来遊するのは５月後半～７月前半頃と，９月後半～12月前半頃の年２回で，いずれも伊予灘から移入して伊予灘へ移出するものとみられた。

2．５月後半～７月前半の回遊は産卵群によるもので，来遊群の分布域の水温は15～22℃であった。

3．９～12月の回遊は索餌期の回遊で，水温の下降期に行われるが，移入期の上限水温は24℃（水深10m），移出期の下限水温は12～13℃であった。

4．この時期の回遊群は豊前海沿岸域まで回遊するものと，周防灘東部の比較的沖合域へ滞留するものの２群に分かれているようであった。

5．来遊量（尾数）の相対的な比較をすると，９～12月の間のピーク時の来遊量は，５～７月のそれの６倍程度の大きさがあった。

文　　献

中国四国農政局統計情報部，1980：昭和53年瀬戸内海の漁業，中国四国農林統計協会協議会，149p.

中国四国農政局統計情報部，1981：昭和54年瀬戸内海の漁業，中国四国農林統計協会協議会，131p.

中国四国農政局統計情報部，1982：昭和55年瀬戸内海の漁業，中国四国農林統計協会協議会，137p.

中国四国農政局統計情報部，1983：昭和56年瀬戸内海地域の漁業，中国四国農林統計協会協議会，153p.

中国四国農政局統計情報部，1984：昭和57年瀬戸内海地域の漁業，中国四国農林統計協会協議会，141p.

藤本　実，1984：黒潮大蛇行と南西海域の黒潮変動，南西水研ニュース，№31，２－４.

岸田　達，1983：1981年瀬戸内海中西部域におけるサワラ卵稚仔の分布について，第15回南西海区ブロック内海漁業研究会報告，南西水研，39—46.

小中邦夫，1961：豊後水道におけるサワラについて，大分水試調査研究報告，**1**，68—78.

工藤勝宏，1968：豊後水域におけるサワラについて－Ⅰ．大島付近の漁況と魚体の大きさ，漁海況予報普及資料，４号，大分水試，57—65.

工藤勝宏，1978：豊後水域におけるサワラについて－Ⅱ．1972年の国東半島周辺における流しさし網漁況，大分水試調査研究報告，**10**，19—25.

工藤勝宏，1982：1975—'79年の別府湾におけるサワラ流しさし網漁況，第14回南西海区ブロック内海漁業研究会報告，南西水研，59—62.

能津純治，1967：豊後水道におけるサワラの回遊について，漁海況予報普及資料，２号，大分水試，１－９.

田中昌一，1957：資源量の相対指数と有効漁獲努力量，東海区水研報，**17**，１—13.

山口県・福岡県・大分県，1975：西瀬戸地域漁業調査報告書　昭和46～49年度，245p.

南西水研報
Bull. Nansei Reg. Fish.
Res. Lab. No. 18, 1985

紀伊水道及びその外域における黒潮蛇行期と非蛇行期の平均水温について

坂 本 久 雄

Mean Temperature in and outside of Kii Strait during the Kuroshio with and without Meander

Hisao SAKAMOTO

The Kuroshio flow South of Japan which essentially governs the oceanographic condition in Nansei Coastal Region including Kii and Bungo Straits can be subdivided into two patterns: the Kuroshio with meander (A pattern—A period) and the Kuroshio with no meander (B, C, D, N pattern—N period).

The difference between the two mean temperatures in and outside of Kii Strait, which were averaged individually in A (July 1975—Dec. 1979) and N (Jan. 1970—June 1975) period, was discussed.

The results were as follows.

1. Generally the mean temperature during A period are slightly lower than that during N period. But the appearance of this slightly lower temperature is very complicated and unsystematic in time and space.
2. This complexity in this region may be caused by the short period fluctuations of the Kuroshio which are more dominant during A period than N period.
3. In Kii Strait and adjacent seas, it is recommended to calculate mean temperatures individually in the period of A and N period and to use properly according to the demand.

紀伊半島から房総半島沖の黒潮内側域に発生する冷水塊は，規模が大きくて，２～９年の長期にわたって存在するA型と，規模が小さくて，６ヶ月以内に消滅するB，C型の３タイプに分類されている（吉田　1961)。さらに，これらの冷水塊と密接に関連する黒潮流路は，A，B，C，D，N型の５タイプに分類されている（二谷　1969)。また，岡田（1978）は，黒潮大蛇行（A型流路）の存在が，全観測期間の約40%に達し，大蛇行が黒潮の安定した流路の一つであることを見出している。

このように，本州南方海域の海況は，黒潮蛇行期（A型期—A型流路）と非蛇行期（N型期—

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B，C，D，N型流路）に大別できる。

ところで，或る時期における海況が，どのような状況下にあるかを判断する方法として，水温の平年偏差値がよく用いられる。この平年偏差値の基準となる平年値を計算する際に，同質のものを平均化することと，異質・同質のものを混ぜて平均する場合とを，はっきり区別して検討する必要のあることを，中村（1977）は指摘した。

例えば，藤本・友定（1980）は，本州南東沿岸の海況を黒潮の蛇行期と非蛇行期に区分して，海域毎の平均水温分布の相違について検討し，海域毎に系統的な差違の生ずることを明らかにした。また，杉村（1979）は，潮岬周辺海域では黒潮離岸時に夏季低温現象が出現すると述べている。

これらの例は，それぞれの海域で平均値を取り扱う場合，基本となる海況を明瞭に区別すべきことを物語っている。

南西海域の沿岸海況は，第一義的には黒潮の影響下にある。また，四国沖～紀伊半島沖の黒潮は，A型冷水塊の存在によって，それのない期間と比べ全く異なった流況を示すから，沿岸海況を論ずるに当って，先ず両期間での平均値に相違が生じているかどうかを検討することが必要である。

本報では，沿岸海況の海候学的検討の第一歩として，遠州灘沖冷水塊の西側に位置する紀伊水水道及びその外域において，黒潮流路のA型期とN型期別に求めた平均水温の相違を検討した。

本文に入るに先立って，本研究の機会を与えられた杉浦健三海洋部部長に感謝の意を表します。また，適切な助言と校閲をいただいた藤本実海洋部第一研究室室長に対し，深謝の意を表します。

資料及び方法

ここで用いた資料は，漁海況予報事業による1970年1月～1979年12月の間に，徳島県水産試験場が観測した紀伊水道定線19点，海部沿岸定線18点と，和歌山県水産試験場による紀伊水道定線12点，和歌山沿岸定線15点の計64点である（Fig. 1）。

黒潮流路のA型期（1975年7月～1979年12月）とN型期（1970年1月～1975年6月）の平均水温は，各定線の定点毎に月別，層別に計算した。そして，A型期とN型期の平均水温差を計算した。すなわち，プラスはA型期の方がN型期に比べて水温が高く，マイナスはA型期の方が低いことを意味する。

なお，本報ではこの水温差を，次の階級区分で表現する。

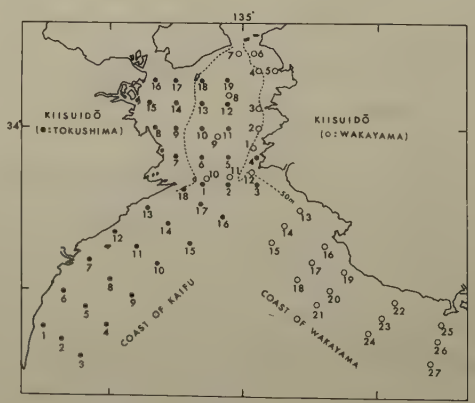

Fig. 1　Station location
Observations were carried out by Tokushima and Wakayama prefectural Experimental Stations.

1.5℃ ＜		かなり高め
0.5℃ —	1.4℃	高　　め
−0.4℃ —	0.4℃	ほぼ等温
−1.4℃ —	−0.5℃	低　　め
−1.5℃ ＜		かなり低め

結果と考察

研究期間における黒潮流軸変動

Fig. 2-a, b に大王埼，潮岬・室戸岬正南沖における黒潮流軸位置の変動を示した（南西海区漁場海況概報№23～№77）。

大王埼正南沖における黒潮流軸位置は，1970年1月～1975年7月の期間ほぼ距岸60～70マイルにあって，比較的安定した接岸状況を示していた。1975年7月以降は急速に離岸し，1977年春に一時的に接岸したが——これは，遠州灘冷水塊の切離によるもの（上平・南　1978）である——，以後1979年7月まで著しく離岸していた。1979年8月以降は，急速に接岸傾向に転じたが，統計期間末の1979年12月は距岸105マイルにあり，未だ接岸過程にある。

室戸岬正南沖では，1970年1月～1975年6月の期間，距岸25マイル附近を中心に小さい離接岸変動を繰返しながら，接岸状況にあった。しかし，1975年7月に距岸95マイルとなり著しく離岸した後，徐々に離岸傾向が強まり1978年4月には距岸145マイルに達した。その後は，大きく離接岸変動し，1979年12月には距岸35マイルにあった。

潮岬正南沖は，室戸岬沖よりも離接岸変動が明瞭であり，1970年1月～1975年6月の期間は接

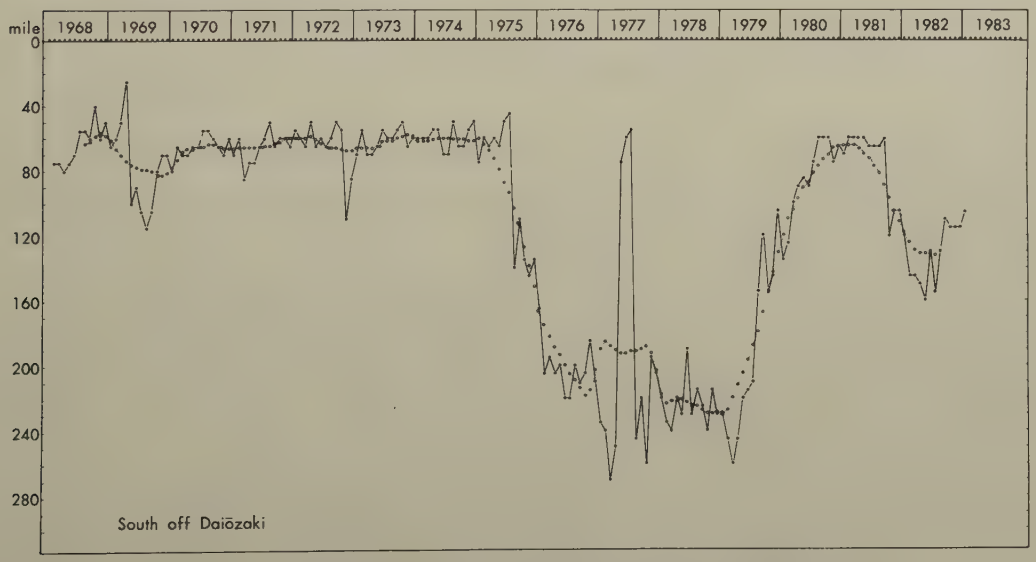

Fig. 2-a　Fluctuation of the Kuroshio axis, South off Daiozaki.
●: Observed values
○: Moving averaged values

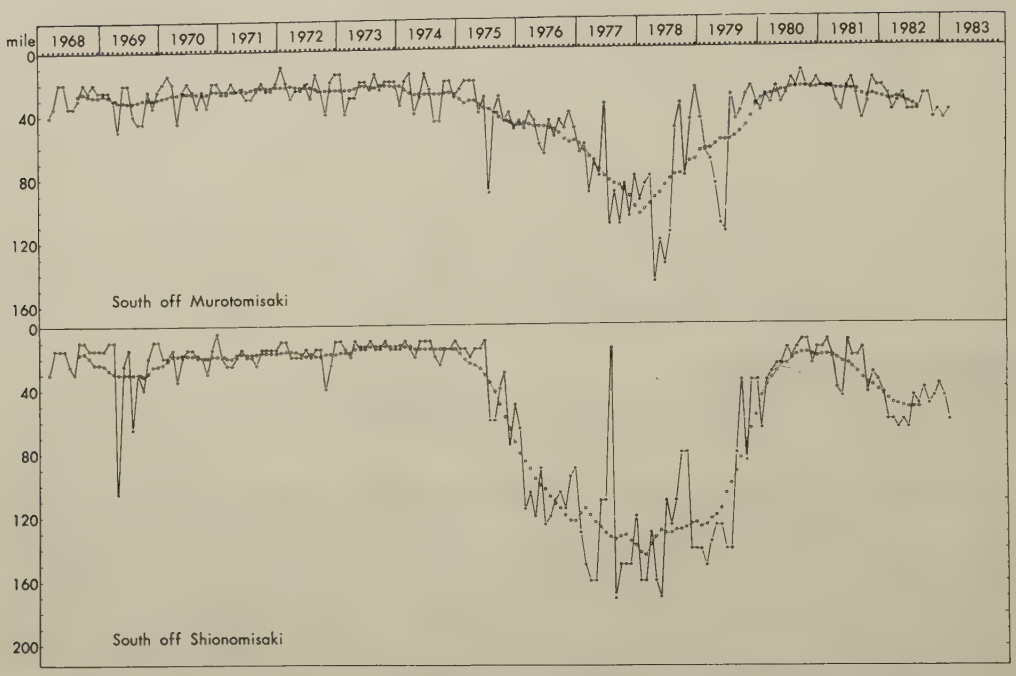

Fig. 2-b　Fluctuation of the Kuroshio axis, South off Cape Murotomisaki (upper) and South off Cape Shionomisaki (lower).
●: Observed values
○: Moving averaged values

岸，1975年7月～1979年12月の期間は離岸していた。

以上のことから，遠州灘沖では1975年7月～1979年12月の期間，黒潮内側域に大型の冷水塊が存在し，黒潮はその沖側を大きく蛇行していたことが明確である。すなわち，本報でのA型期は1975年7月～1979年12月の期間であり，N型期は1970年1月～1975年6月の期間に相当する。

年平均水温差の水平分布

紀伊水道が海深70mに達しないため，ここでは0，10，30，50m層におけるA型期とN型期の年平均水温差分布（Fig. 3）について検討した。

0，10，30m深における年平均水温差の分布は，ほぼ同じ様相を示し，紀伊水道入口，和歌山沿岸南部で“低め”であり，他の海域では“ほぼ等温”である。50m深は，和歌山沿岸北部で“ほぼ等温”であるが，他の海域は“低め”，とくに和歌山沿岸南部は“かなり低め”である。なお，“高め”を示す海域は，各深さに共通してみられない。

これらのことから，当該海域の0～50m層におけるA型期の水温は，N型期に比べ低温で推移することが推察される。また，和歌山沿岸の海況は，北部と南部に区分することができる。

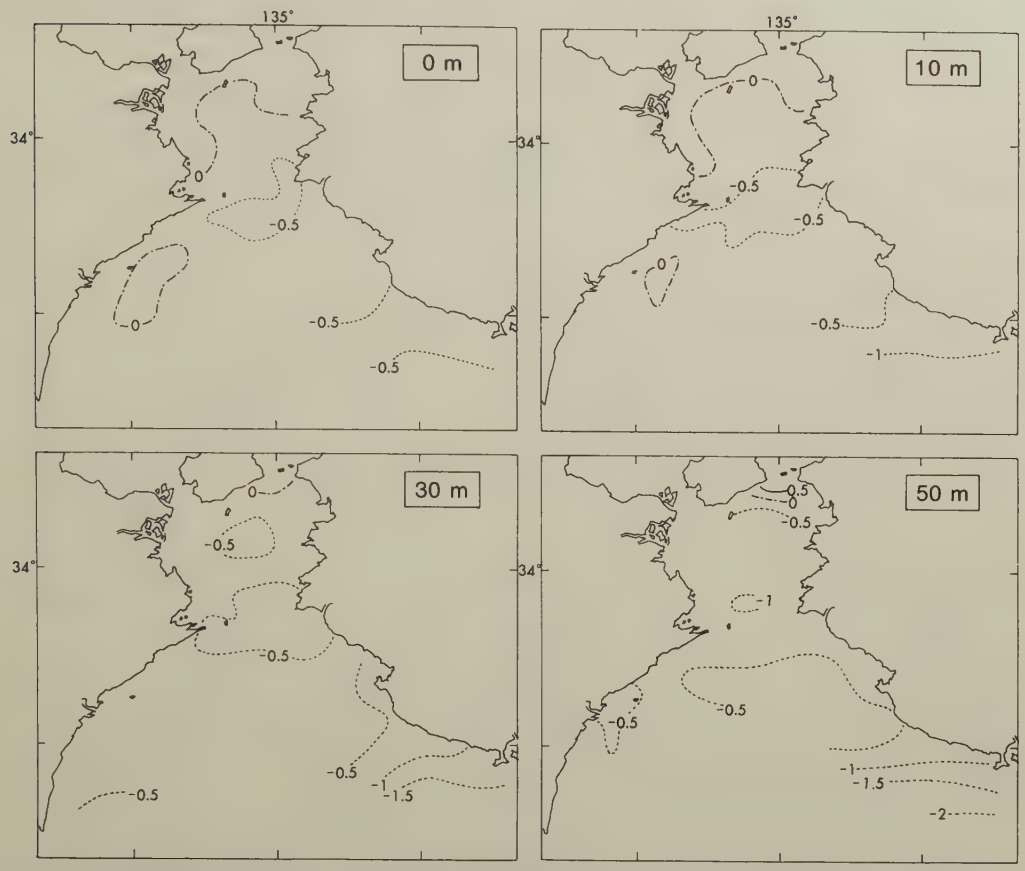

Fig. 3 Distribution of deviation between annually averaged temperatures in A and N period.
A: July 1975—Dec. 1979
N: Jan. 1970—June 1975

月別平均水温差の分布

10m深と50m深におけるA型期とN型期の月別平均水温差の分布を Fig. 4, 5 に示す。

紀伊水道での月別平均水温差の分布は，10m深では変化が大きく，50m深では小さい。紀伊水道には外洋水，陸水，内海水が複雑に，しかも不規則に流出入するため，低密度な陸水，内海水の混入する表層ほど，一様性に欠けるものと考えられる。

一方，海部沿岸の10，50m深における分布状況は，各月とも紀伊水道に比較すれば変化が小さい。また，和歌山沿岸では年平均水温差分布でもみられたように，10，50m深とも月毎の分布は北部と南部で様相が異なる。ただし，それぞれの海域内での分布変化は小さい。これらの海域は，外洋に面したところであり，外洋水の影響を直接に受け，その流入方向，勢力により，海況が一方的に支配されていることを示唆している。

Table は Fig. 4, 5 の定点別平均水温差を海域毎に平均し，それを階級区分で表示したものである。なお，それぞれの海域の特長を明瞭に表現するため，紀伊水道の指標として和歌山県の st. 1～st. 9，徳島県の st. 4～st. 19 の観測資料を用いた。海部沿岸では st. 1～st. 15の観測資料を

用いた。和歌山沿岸は水温差の水平分布が北部と南部で異なった様相を示すので分離し，北部は st. 13～st. 21，南部は st. 22～st. 27 の観測資料を用いた。

10，50m深では，各海域とも“高め”を示す場合が年間0～2ヶ月であり非常に少ない。一方，“低め”～“かなり低め”を示す場合は，年間4～8ヶ月ある。とくに，和歌山沿岸南部は“かなり低め”を示す場合が，10m深で4ヶ月，50m深で7ヶ月ある。これらのことから，50m以浅

Fig. 4 Distribution of deviation between monthly averaged temperatures at 10 meter depth in A and N period.
A: July 1975—Dec. 1979
N: Jan. 1970—June 1975

Fig. 5 Distribution of deviation between monthly averaged temperatures at 50 meter depth.

A: July 1975—Dec. 1979

N: Jan. 1970—June 1975

Table Schematic representation of the deviation between annually averaged temperatures in A and N period at subdivided districts.
A: July 1975—Dec. 1979
N: Jan. 1970—June 1975

	Sea Area	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
10 meter depth	Kiisuido	0	−	0	−	0	−	0	−	0	0	0	+
	Coast of Kaifu	0	0	−	−	0	−	0	−	0	+	0	+
	North Coast of Wakayama	0	−	0	=	−	0	0	−	0	0	0	+
	South Coast of Wakayama	=	−	−	=	=	−	0	=	0	0	−	0
50 meter depth	Kiisuido	+	0	0	−	0	=	−	=	−	0	−	+
	Coast of Kaifu	0	0	−	−	0	−	0	=	=	+	0	+
	North Coast of Wakayama	0	−	0	−	0	0	0	=	−	0	0	+
	South Coast of Wakayama	=	=	0	=	=	=	0	=	=	0	−	0

＋：0.5°～1.4°C　　0：0.4°～−0.4°C　　−：−0.5°～−1.4°C　　＝：−1.5°C＜

ではA型期の場合がN型期より低温であることが推察できる。なかでも，和歌山沿岸南部では，その現象が顕著である。

海域毎の月別平均水温差鉛直分布

Fig. 6は，各定点でのA型期とN型期の平均水温差を，海域毎に月別，水深別に平均したものである。なお，各海域の区分は Table に準じた。

各海域の平均水温差の月別鉛直分布にみられる特長は，上層（0～50m層）では8，9月を除き，各海域ともほぼ一様な状況にあることである。海部沿岸，和歌山沿岸北部・南部は，1，2月に0～200m層の間の変化が小さい。8月は各海域とも30～100m層で“かなり低め”を示し，

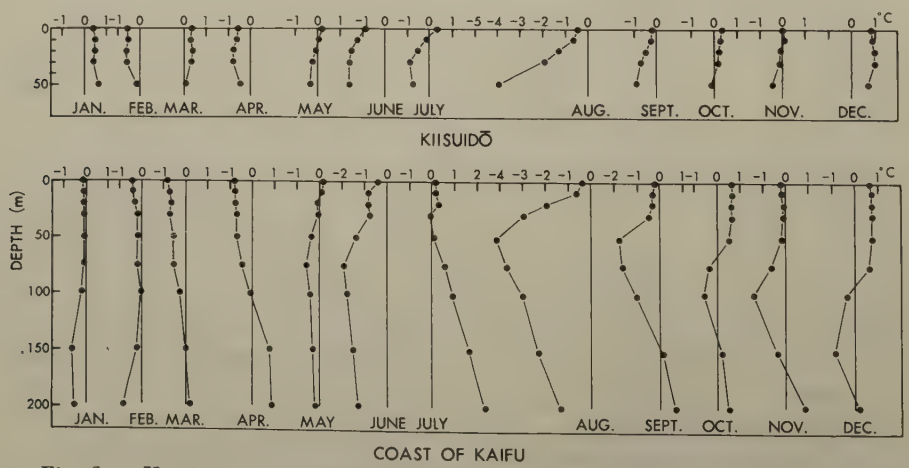

Fig. 6-a Vertical distribution of deviation between monthly averaged temperatures in A and N period at Kii Strait (upper) and Coast of Kaifu, Tokushima Prefecture (lower).
A: July 1975—Dec. 1979
N: Jan. 1970—June 1975

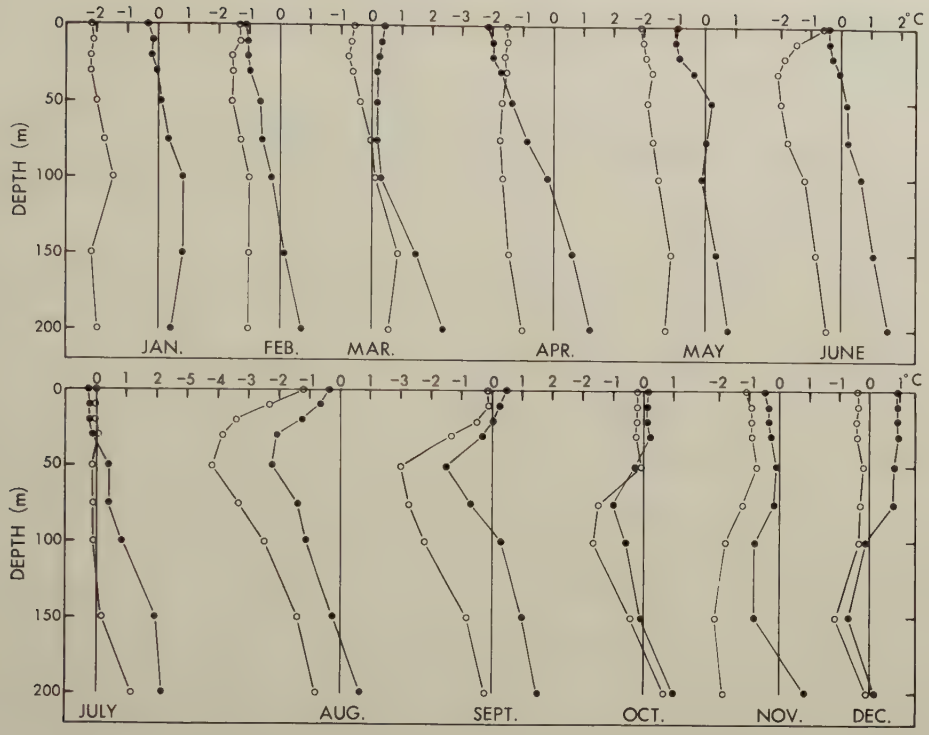

Fig. 6–b Vertical distribution of deviation between monthly averaged temperatures in A and N period at Northern Coast of Wakayama Prefecture (•) and Southern Coast of Wakayama Prefecture (○).
A: July 1975—Dec. 1979
N: Jan. 1970—June 1975

A型期における顕著な低温現象が認められる。この低温現象は，8月の50m深で－3℃～－4℃のピークを示し，12月にかけて徐々に弱まるとともに，深くなる傾向がある。各海域，月，層とも大部分が“ほぼ等温”または“低め”を示すなかで，和歌山沿岸北部では150～200m層で“高め”を示す月が多い。また，海部沿岸においても150～200m層で年間3～4ヶ月“高め”を示す。和歌山沿岸南部は，下層で“高め”を示す月が若干あるが，全般的にみれば他の海域よりもA型期の低温現象が顕著に現われている。

中村（1977），杉村（1979）は，黒潮離岸時には駿河湾～遠州灘および相模湾，潮岬周辺域で夏季低温現象が生じることを指摘している。本研究においても，紀伊水道及びその外域において，ほぼ同じ現象の生じることが確認された。但し，和歌山沿岸北部では100m以浅で“低め”～“かなり低め”であるが，150～200m層では“高め”を示し，他の海域とは若干異なった海況を示す傾向がある。この夏季低温現象は，8月の50m深をピークに顕著に出現し，その後，月の経過とともに弱まり，ピークは深くなる傾向にある。そして，1，2月には0～200m層間でほぼ一様となる。これは，秋季から冬季にかけて対流期に入り鉛直混合が盛んになるためであろう。

和歌山沿岸南部のA型期における低温現象について，藤本・友定（1980）は0，50，100，200mの各深度，各季節に共通してみられることを指摘しているが，本報の結果では，200m層で“高

め”を示す場合が認められた。この違いは取扱った資料の期間が，A型期はほぼ同じ長さであるが，N型期は本報の場合が短かく，約半分であることから考えると，この資料期間の長短に起因する誤差であると考えられる。

以上の結果を総合すると，紀伊水道及びその外域における水温は，全般的にみると，黒潮蛇行期には低めに経過する。したがって，平均値としては蛇行期と非蛇行期別に，区別して使い分ける必要のあることを示唆している。

しかし，A型冷水塊の影響を直接受ける熊野灘～遠州灘海域での整理（藤本・友定　1980）に比べると，海況差の現われ方が明確でない。この理由は以下のように考えられる。

熊野灘～遠州灘沖の黒潮流軸は，A型冷水塊が出現するとその東西変動によって変化するが，はるか沖合に位置するので，その影響が熊野灘～遠州灘の海域に直接及ぶことはない。したがって，この海域は蛇行期，非蛇行期間できわめて安定した系統的な海況の差を生じるのであろう。

これに対し，南西海域東部の黒潮は，A型冷水塊の影響で離岸傾向をとる中で，非蛇行期にはみられなかったやや規模の大きい離接岸変動をすることが知られている（藤本　1984)。この黒潮の離接岸変動に伴なって，蛇行期間中といえども，外洋水（黒潮系水）が，室戸岬東沖から海部沿岸沿いを北上する場合，和歌山沿岸沖を北上する場合，潮岬沖から和歌山沿岸沿いを北上する場合，そして，外洋水の流入がなく，内海系水，沿岸系水の沖合への流出が顕著となる場合が生じてくる（殿谷　1981)。このことからすれば，紀伊水道及びその外域では，黒潮の蛇行期においても，黒潮分枝流の派生の仕方によって，その海況が大きく変動する。すなわち，両期間できわ立った差の出てない理由が，ここに求められる。

今後は海洋観測資料の蓄積をより積極的に進め，蛇行期と非蛇行期による海況の違いをより明確にするとともに，より微細な黒潮変動に対応する沿岸海況についても，検討を進める必要があろう。

要　　約

紀伊・豊後両水道を含む南西海区沿岸域の海況を基本的に支配する黒潮は，大蛇行流路（A型流路—A型期）と非蛇行流路（B，C，D，N型流路—N型期）の二つに分けることができる。ここでは，紀伊水道及びその外域において，A型期（1975年7月～1979年12月）とN型期（1970年1月～1975年6月）別に求めた平均水温差について検討した。得られた結果は，次の通りである。

1．全般的にみてA型期の平均水温は，N型期よりやや低い傾向にある。しかし，低温傾向の出現は非常に複雑で系統的でない。

2．当海域でみられる平均水温差の複雑さは，N型期よりA型期に，より卓越する黒潮の短期変動によるものと思われる。

3．紀伊水道及びその外域では，海況別（黒潮の蛇行，非蛇行）に平均値を求め，用途に応じて使い分ける必要がある。

文　　献

藤本　実，1984：黒潮大蛇行と南西海域の黒潮変動，南西水研ニュース，31，2—4.

藤本　実・友定　彰，1980：黒潮大蛇行期・非蛇行期からみた本州南東沿岸域の平均水温分布について，東海水研報，103，17—30.

上平悦朗・南　秀人，1978：1977年5月大冷水塊の切離，黒潮大蛇行と大冷水塊—その消長と予測に関する研究—，昭和52年度文部省科学研究費総合研究A研究報告書，61—75.

中村保昭，1977：駿河湾ならびに隣接海域の海況変動，水産海洋研究会報，30，8—38.

二谷穎男，1969：最近数年の黒潮の変動について，水産海洋研究会報，14，13—18.

岡田正実，1978：黒潮の大蛇行歴（1854～1977）と潮汐観測，海洋科学号外，2，81—88.

杉村允三，1979：潮岬周辺海域の海況について，水産海洋研究会報，34，106—110.

殿谷次郎，1981：大型冷水塊形成による黒潮流及び徳島沿海の海況変動，徳島水試事業報告（昭和54年度），128—135.

吉田昭三，1961：遠州灘冷水塊と黒潮の変動について（その1），水路要報，67，54—57.

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Morphology and Ecology of Four Types of the Genus *Paraprionospio* (Polychaeta: Spionidae) in Japan

Kyoichi TAMAI

Abstract

Well-known eutrophic indicator species, *Paraprionospio pinnata* (EHLERS, 1901) was studied morphologically and ecologically in Japan. This species in Japan can be divided into the four types (A, B, CI, CII) on the basis of the external morphology, areal distribution and habitat preference. They are recognized as discrete species respectively. The filament at the base of the third branchia, pigment spots on the peristomium, transverse dorsal crests, ventral bilobed ridge on setiger 8, adult body size and so on, which were hardly or not used previously, serve for the morphological classification. Type A is a species restricted in inshore waters shallower than 20m in water depth. Type B is an inland sea mud or muddy sand bottom species. Type CI is an eurytopic species widely distributed in various environment. Type CII is an offshore waters species. Only types A and B are useful for eutrophic indicators. These two types do not have an opportunistic nature. Type A has a good adaptation to eutrophic environments in regard to both physiological tolerance and the timing of the settlement. Type B chiefly depends on physiological tolerable ability for the prosperity in eutrophic areas.

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1 Methods
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I Introduction

In Japan, *Paraprionospio pinnata* (Ehlers, 1901) was known as the only species which belonged to the genus *Paraprionospio* (Okuda, 1937; Imajima and Hartman, 1964). Many workers studied this species because it was frequently dominant and conspicuous in benthic communities of the enclosed bays.

Miyadi, Masui and their colleagues carried out the benthic surveys in many bays, and reported that a large number of *P. pinnata* were collected in Beppu Bay (Miyadi, 1941a), Ise Bay (Miyadi, 1941b), Yamakawa Harbor in Kagoshima prefecture (Miyadi and Masui, 1942a), Nanao Bay in Ishikawa prefecture (Miyadi and Masui, 1942b), Tokyo Bay (Masui, 1943), Habu Harbor in Izuoshima (Miyadi et al., 1943) and Uranouchi Bay in Kochi prefecture (Miyadi et al., 1944a). On the basis of these synecological studies, Miyadi et al. (1944b) concluded that *P. pinnata* was one of the typical species which lived in the area with middle embayment degree. Embayment degree is the synthetical index showing the intensity and the type of embayment factors, and is divided into three stages, namely, weak, middle and strong (Miyadi et al., 1944b).

Kitamori (1969) showed that *P. pinnata* could be utilized for the indicator species of organic pollution from the macrobenthic investigations in Tokyo Bay, Osaka Bay and Ise Bay. Subsequently, some other workers also used this species as a pollution indicator (Joh et al., 1969, 1978a; Kawabe, 1975; Sanukida et al., 1979, 1981). Richardson (1971) and Boesch (1973) refered to high tolerance to organic pollution in *P. pinnata*. Simon and Dauer (1977) reported that *P. pinnata* occurred dominantly after the defaunation due to red tide in Tampa Bay, Florida.

As mentioned above, *P. pinnata* seems to be usually distributed in enclosed bays polluted by organic wastes. However, *P. pinnata* was sometimes recorded also in unenclosed waters. For example, Kitamori (1973) and Takahashi and Ishikawa (1976) reported that considerable relative dominance of *P. pinnata* was observed in the open sea coast off the industrial cities. They connected the appearance of the species with local accumulation of organic pollutants below the surf zone, but the pollution load of such localities are much less than those in the enclosed bays. Furthermore, Tamai

(1981) and YOKOYAMA and TAMAI (1981) found the four different types belonging to the genus *Paraprionospio* in Japan, which were distinguished each other by their external morphology and environmental preference. Those findings suggest that the species which has been named *P. pinnata* traditionally in Japan might be separated into several discrete species or comparable taxa. Therefore, the ecological characteristics including life history and the utility as the biological indicators of organic pollution must be also investigated separately in every different morphological type.

Recently, in Osaka Bay (TAMAI, 1982) and Kumihama Bay in Kyoto prefecture (YOKOYAMA, 1982), the life history of *Paraprionospio* sp. (type A) has been studied and the reasons for the prosperity of the type in eutrophic environments have been discussed. UENO and YAMAMOTO (1982) have studied the tolerance to temperature and salinity in *Paraprionospio* sp. (type A).

In this paper, I will describe the morphology, distribution and life history of the four types belonging to *Paraprionospio* in Japan. Furthermore, I will also discuss the utility for environmental indicators of these types and the reason for their prosperity on the basis of their ecological data, the physico-chemical environmental conditions and macrobenthic community structures. Some parts of this paper have already been published (TAMAI, 1981, 1982; YOKOYAMA and TAMAI, 1981).

II Morphological features of the four types of *Paraprionospio*

In Japan, *P. pinnata* (EHLERS, 1901) was known as the only species which belonged to *Paraprionospio* (OKUDA, 1937; IMAJIMA and HARTMAN, 1964). However, the author (TAMAI) and YOKOYAMA have independently found that *Paraprionospio* specimens in Japan are composed of four morphologically different types (TAMAI, 1981; YOKOYAMA and TAMAI, 1981). The morphology of these all types coincides with the original description of *P. pinnata* (EHLERS, 1901), however, they are different one another in detailed morphology as described below. But, it is impossible to identify these four types because the characters treated by us have been almost ignored in the previous morphological studies and even the previous descriptions of *P. pinnata* are taxonomically confused (YOKOYAMA and TAMAI, 1981). Therefore, these four types were provisionally named type A, type B, type CI and type CII. In this section, their morphological features are described briefly according to TAMAI (1981) and YOKOYAMA and TAMAI (1981). Please refer to YOKOYAMA and TAMAI (1981) for further details.

Fig. 1 and Table 1 show the morphology of the four types and the comparison among them. Each type has well-developed peristomial wings and three pairs of pinnate

branchiae beginning on the setiger 1. These are generic characters of *Paraprionospio*. Consequently, these four types apparently belong to this genus. The characters peculiar to type A are the bifoliate branchial lamellas (Fig. 1, d), first appearance site of nonlimbate capillaries in neuropodia (Fig. 1, e) and the transverse dorsal crests on setigers 21-35 (Fig. 1, b). Especially, the dorsal crests are the conspicuous morphological features observed with ease. Type B is characterized by the ventral bilobed ridge on

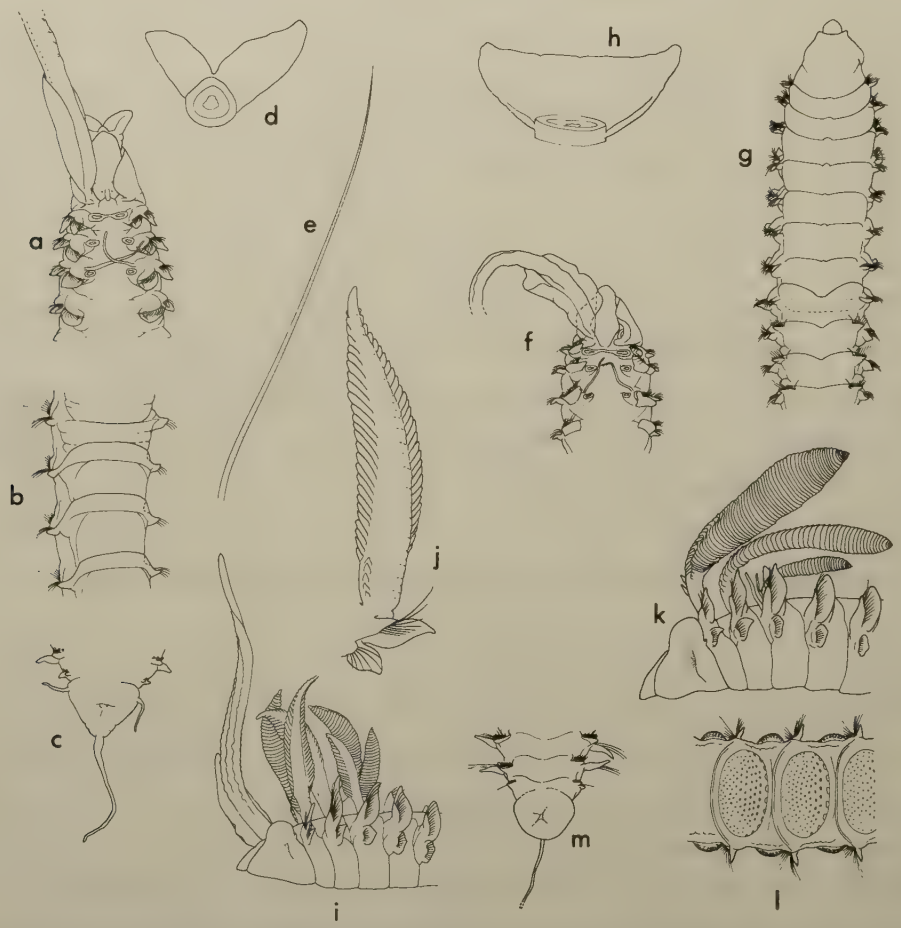


Fig. 1 Morphological features of four types of the genus *Paraprionospio*. Type A: a, anterior end, in dorsal view; b, setiger 20–23, showing dorsal crests, in dorso-lateral view; c, posterior end, in ventral view; d, middle part of the left branchia of setiger 1 in cross section, showing the bifoliate lamella; e, neuropodial nonlimbate capillary. Type B: f, anterior end, in dorsal view; g, anterior end, in ventral view, showing the bilobed ridge in setiger 8; h, middle part of the left branchia of setiger 1 in cross section, showing the flabellate lamella. Type CI: i, anterior end, in lateral view; j, first parapodium with branchia, in anterior view. Type CII: k, anterior end, in lateral view; l, setigers 21–23, in dorsal view, showing transparent dorsal cuticle and interramal pouches; m, posterior end, in ventral view (Yokoyama and Tamai, 1981).

Table 1 Comparison of four types of the genus *Paraprionospio* (Yokoyama and Tamai, 1981)

Characters	Type A	Type B	Type CI	Type CII
Pigment spots on the peristomium	absent	absent	present	present
Papilla on the posterior margin of the peristomium	present	absent	present	present
Shape of the lamellar plate of the branchia	bifoliate	flabellate	flabellate	flabellate
Accessory lamellae on the first branchia	absent	absent	present	present
Filament at the base of the third branchia	present	present	absent	present
First appearance of nonlimbate capillaries in neuropodia	setiger 10	setiger 9	setiger 9	setiger 9
Ventral bilobed ridge on setiger 8	absent	present	absent	absent
Transverse dorsal crests between the notopodia	present on setigers 21–35	absent	absent	absent
Transparent dorsal cuticle	present on setigers 21–35	present on setigers 21–36	absent	present on setigers 21–31
Interramal pouches	absent	usually present	present or absent	present
Lateral anal cirri	present	present	present	absent

Table 2 Maximum specimens of four types of the genus *Paraprionospio*

Types	Max. weight (mg)	Max. length (mm)	Max. width* (mm)	Max. No. of setigers
A Osaka Bay	64.5	53.0	1.76	98
Tosa Bay	230.9	88.1	2.40	113
B	20.3	37.0	1.30	94
CI	112.5	76.0	1.80	111
CII	135.8	67.2	2.05	96

*The width of the fifth setiger excluding parapodia was measured.

setiger 8 (Fig. 1, g) and the small adult size (Table 2). Type CI resembles type CII in the presence of peristomial pigment spots (Fig. 1, i, k), the branchial shape (Fig. 1, i, j, k), size of the adult specimen (Table 2) and so on. However, type CII is distinguished from type CI by the presence of a filament at the base of the third branchia (Fig. 1, k) and the transparent dorsal cuticles (Fig. 1, l), and the absence of the lateral annal cirri (Fig. 1, m).

III Distribution of the four types of *Paraprionospio*

III-1 Methods

Surveys were carried out 33 times in the six areas shown in Fig. 2——Osaka Bay, Hiuchi-nada, Beppu Bay, Kii Channel, Tosa Bay and East China Sea—— from July 8–10,

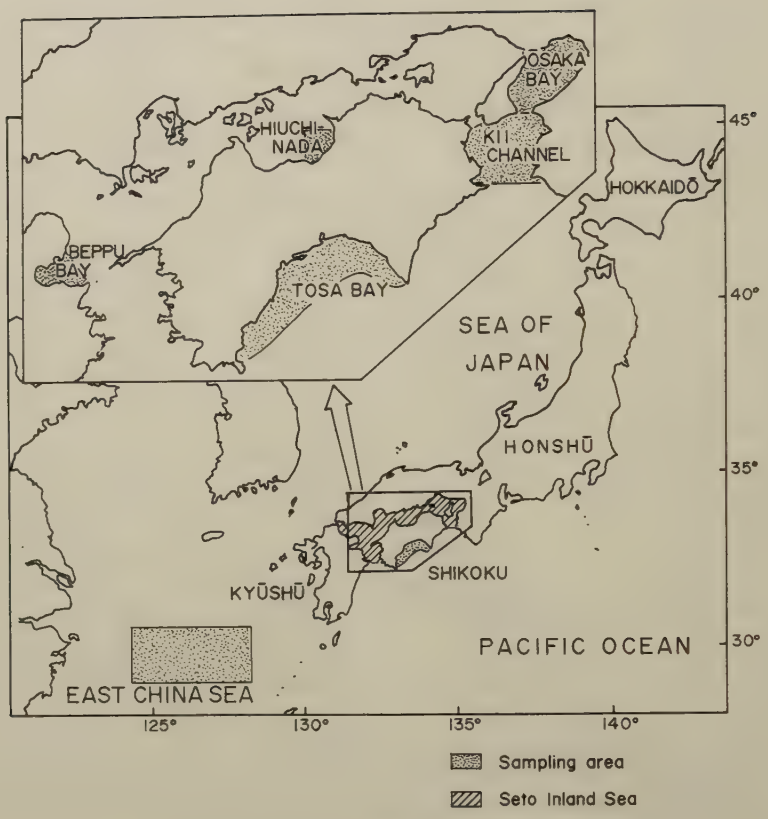


Fig. 2 Map showing the sampling areas.

1975 to June 23-24, 1981. One to five bottom samples were collected at each station using Smith-McIntyre grab sampler (covering area 0.1m^2). Physico-chemical factors usually measured were as follows: temperature, salinity and dissolved oxygen in surface and bottom waters; temperature, total carbon content, total nitrogen content and grain size composition in sediments. Salinity was measured by salinometer, and dissolved oxygen measured by EIL 1520 DO meter or Winkler's method. Sediments of the top 2-3cm were used for analyses. Total carbon content and total nitrogen content were determined by Yanagimoto MT 500 CN corder. Coarse particles were removed from sediment by 1mm mesh sieve and the remaining fine sediment was used for the measurement of total carbon and nitrogen content. Mud content, namely, weight percentage of the silt-clay component, was used for the expression of the results of grain size analysis. Macrobenthic animals were sieved off from sediment with 1mm mesh, or both 0.5mm and 1mm mesh sieves, and fixed with formalin. In this chapter, only the specimens obtained with 1mm mesh were usually used to describe the distribution of *Paraprionospio* and the benthic community structure. 0.5mm mesh samples will be used in the next chapter.

III-2 Distribution

In this section, the relation between the distribution of *Paraprionospio* and five fundamental factors—water depth, mud content and total nitrogen content in sediment, number

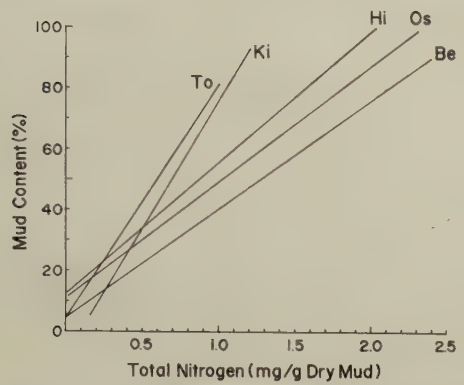


Fig. 3 Relation between total nitrogen and mud content in sediment.

Osaka Bay (Os): MC=38.0TN+11.6 (r=0.82, n=142)

Hiuchi-nada (Hi): MC=43.2TN+12.2 (r=0.91, n=49)

Beppu Bay (Be): MC=35.5TN+4.8 (r=0.91, n=39)

Kii Channel (Ki): MC=84.0TN−8.5 (r=0.89, n=22)

Tosa Bay (To): MC=76.0TN+5.0 (r=0.56, n=60)

MC; mud content, TN; total nitrogen, r; correlation coefficient, n; the number of samples.

All regression equations are significant ($P<0.001$).

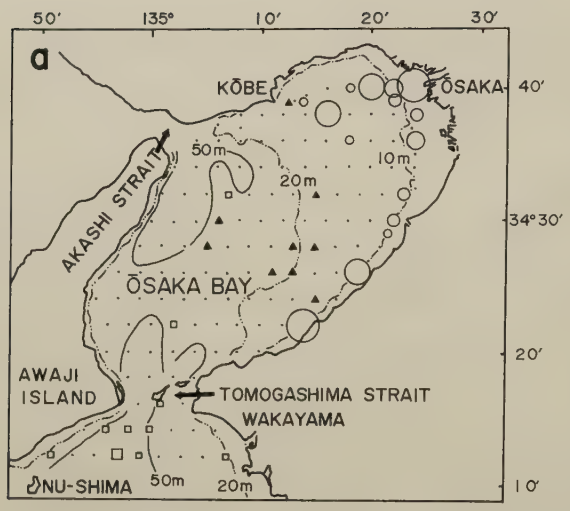
Table 3 Sampling data of the genus *Paraprionospio*

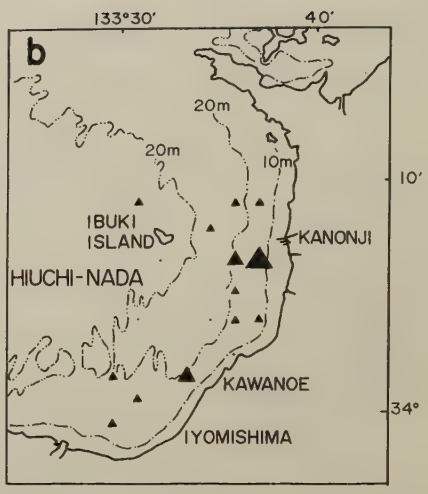
Surveyed area	Date	No. of samplings	surveyed depth range (m)	No. of collected specimens				Distributional depth range (m)				Sediments*1			
				A	B	CI	CII	A	B	CI	CII	A	B	CI	CII
OsakaBay	Dec. 8–13, '76	89	10–117	875*2	10	4		10–20	14–51	45		MS–M	M	MS	
	June 20–July 4, '77	148	6–93	521	11	17		7–18	14–48	15–64		GS–M	M	S–MS	
Hiuchi-nada	Aug. 4–5, '77	32	11–24		3				10–22.5				MS–M		
	June 6–7, '78	40	14–26		4				16				M		
	Aug. 28–29, '78	44	13–23		6				13.5–23				MS–M		
	Nov. 30, '78	24	9–24		96				20–24				M		
	May 27–28, '79	36	12–26		65(18)*3				13–26				M		
	Aug. 22–23, '79	36	12–24		33				14–24				MS–M		
	Dec. 13–14, '79	17	10–24		37(50)				10–24				MS–M		
	June 11–12, '80	18	14–24		30(25)				14–24				MS–M		
	Aug. 31–Sept. 1, '80	18	8–23		5(2)				12–22				MS–M		
	Feb. 3–5, '81	16	10–25		122(35)				13–25				MS–M		
	June 23–24, '81	18	11–24		106(51)				14.5–23				MS–M		
Beppu Bay	Nov. 30–Dec. 2, '75	51	18–74		48	69			26–54	26–60			M	M	
	July 2–4, 76	76	15–72		39	294			15–46	37–58			MS–M	S–M	
	Nov. 29–30, '77	76	8–72		33	16			20–53	8–27			M	MS	
Kii Channel	June 12–13, '76	22	20–86		4	5			20–42	38–67			M	S–MS	
Tosa Bay	Nov. 17–20, '75	70	20–312				21				56–98				MS
	June 3–12, '76	52	22–110			38	37			24–110	40–89			S–MS	MS
	Feb. 16–17, '77	17	15–50	79		8	9	15		15–50	50	S		S–MS	MS
	June 13–14, '77	22	15–50	142		17	2	15		15–45	35–50	S		S–MS	MS
	Oct. 12–13, '77	22	15–50	67		3	7	15		25	50	S		S	MS
	Apr. 25, 78	11	5–70	14		9	7	10–15		15–70	35–70	S		S–MS	MS
	June 27, '78	20	5–70	21		7	10	10–15		15–70	35–70	S		S–MS	MS
	Aug. 23, '78	20	5–70	318		4	2	10–15		15–70	45–70	S		S–MS	MS
	Oct. 24, '78	20	5–70	42			9	10–15			35–70	S			MS
	Dec. 18 '78	20	5–70	219(10)		(1)	22(4)	15		35	35–70	S		MS	MS
	Mar. 6, '79	20	5–70	27		4	18	15		15–45	25–70	S		S–MS	S–MS
	Apr. 26, '79	18	5–80	9		1	13(1)	15		45	35–80	S		MS	MS
	June 22, '79	18	5–80	57		4(1)	10	15		25–80	35–80	S		S–MS	MS
	Nov. 29, '79	18	5–80	17(5)		1	1(3)	15–25		70	70–80	S		MS	MS
	Feb. 7, '80	18	5–80	9	1		17(1)	15	45		45–80	S		MS	MS
East China Sea	July 8–10, '75	18	52–118		1	1			70	52			MS	MS	
Total		1145		2417(15)	654(181)	502(2)	185(9)								

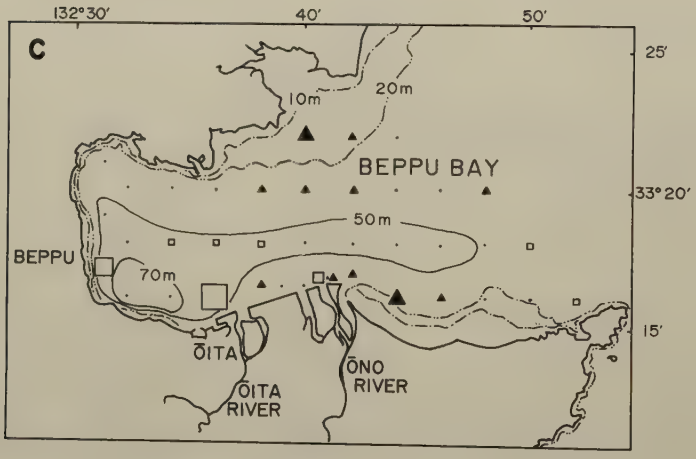
*1 GS; gravelly sand. M; mud. MS; muddy sand or sandy mud. S; sand.

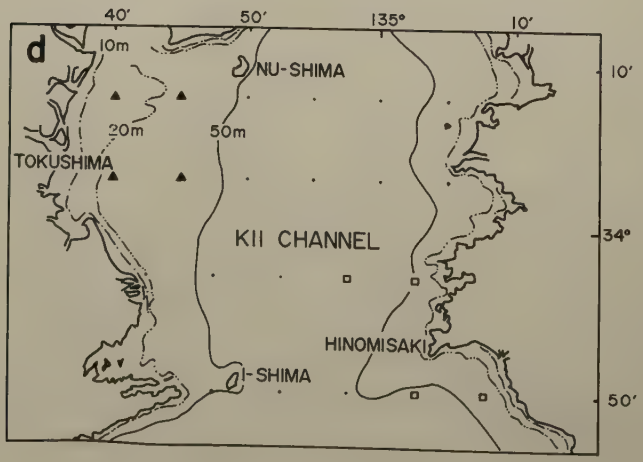
*2 Number of specimens retained on 1mm sieve.

*3 Figure in parenthesis shows number of the small specimens which passed through 1mm sieve and retained on 0.5 mm sieve.









Ind./m²	Type			
	A	B	CI	CII
1-49	○	▲	□	■
50-99	○	▲	□	■
100-199	○	▲	□	
200-499	○		□	
500≤	○			

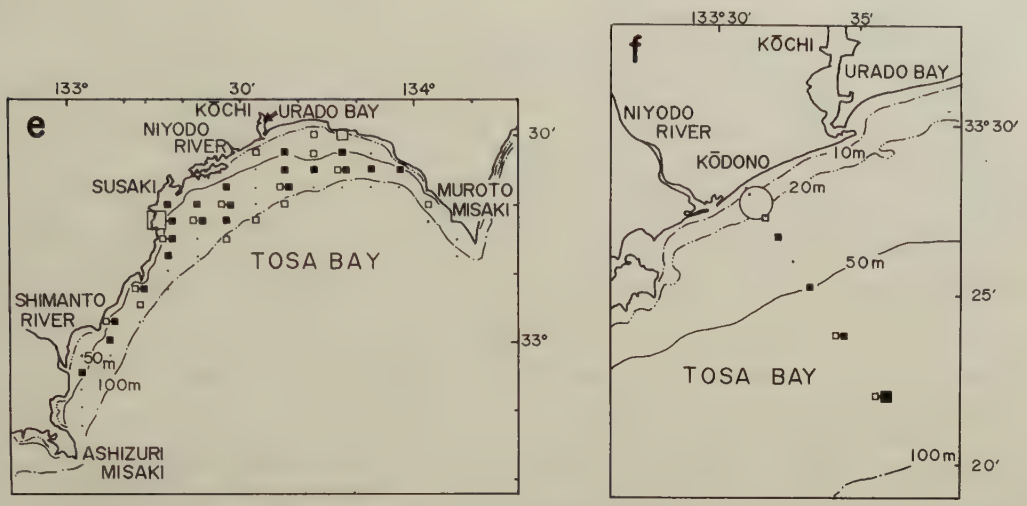


Fig. 4 Distribution of *Paraprionospio*.
a; Osaka Bay from June 20 to July 4, 1977.
b; Hiuchi-nada on May 27–28, 1979.
c; Beppu Bay on July 2–4, 1976.
d; Kii Channel on June 12–13, 1976.
e; Tosa Bay on June 3–12, 1976.
f; off Kōdono in Tosa Bay on June 22, 1979.

of species and density of macrobenthic animals—was investigated. In general, macrobenthic distribution has been known to be largely influenced by these physico-chemical and biological factors (Miyadi et al., 1944b; Sanders, 1958; Kitamori, 1963; Rhoads and Young, 1970; Rhoads, 1974; Tsuchiya and Kurihaka, 1976; Nakao, 1982 etc.). Water depth is undoubtedly one of the most important factors affecting the distribution of marine organisms. Mud content indicates hydrographical conditions. Total nitrogen content is the indicator of organic materials in sediment which are used for the food of surface and subsurface deposit feeders. Mud content and total nitrogen content in sediment were directly related but the relation between them was rather different in each area (Fig. 3). The pooling of the regression equations was possible only between Tosa Bay and Kii Channel ($P<0.05$). So mud content and total nitrogen content should be treated separately. Number of species and density were used for the description of the benthic communities. The outline of the sampling data of *Paraprionospio* are summarized in Table 3. Fig. 4 shows the distribution of *Paraprionospio* in each surveyed area and Figs. 5-7 show the relation between the distribution and the five factors. The relation between water depth and mean density of the four types of *Paraprionospio* is shown in Table 4. The seasonally fluctuating factors, such as temperature, salinity, dissolved oxygen, will be mainly dealed with in the next chapter.

General description of the surveyed areas

Osaka Bay: This bay is located at the eastern part of the Seto Inland Sea. The bay is almost enclosed by Honshu and Awaji Island and has an elliptical outline. The northeastern half of the bay is shallower that 20m, and the bottom slope is descending gradually toward the Akashi and Tomogashima Straits. All area but nearshore and strait regions is mainly covered with mud. JOH et al. (1978a, b) have reported that in the northeastern part of the bay the organic pollution of sediment is conspicuous except the quite shallow nearshore region and oxygen deficiency in the bottom water occurs in summer, while in the southwestern part the sediment is nearly normal and the oxygen deficiency occurs only weakly.

Hiuchi-nada: This area is nearly central part of the Seto Inland Sea. In this study the eastern part of Hiuchi-nada was surveyed, where very flat mud bottom of about 20m in depth develops. Marked organic polluion is observed in this area (OKAICHI et al., 1971) and the oxygen deficiency in the bottom water happens in summer stratification (YANO, 1977; OCHI et al., 1978).

Beppu Bay: This bay is situated at the western part of the Seto Inland Sea and has rectangular outline. Depth of the bay mouth is about 40m. The innermost part of the bay reaches more than 70m in depth, and forms a small basin-like depression. Almost all area of the bay is covered with mud, but the bay mouth is covered with sand or muddy sand. In the area more than 60m in depth, the dissolved oxygen deficiency occurs fairly strongly at least from July to November (SHIOZAWA et al., 1977), and this influences macrobenthic community structure (TAMAI, 1980).

Kii Channel: The northern part of the Kii Channel connects with Osaka Bay by the Tomogashima Strait and with Harima-nada by the Naruto Strait. The southern part of this channel opens to the Pacific Ocean and is influenced by the Kuroshio branch. The northwestern part, off Tokushima, is comparatively shallow and covered with mud. The other part is deep and sand or muddy sand bottom.

Tosa Bay: Tosa Bay opens to the Pacific Ocean widely and is semi-circular in outline. This bay is influenced by the Kuroshio strongly. Sediments change from sand to muddy sand with increasing water depth and mud content of the sediment is the highest at the depths of 60–90m. With further increase of the water depth, sediments again tends to become coarser (TAMAI, 1981).

East China Sea: Surveyed area is on the continental shelf of the northern part of East China Sea. The water depth ranged from 52m to 118m. The sediment consisted of sand or muddy sand.

Distribution

Type A: This type was collected in Osaka Bay and Tosa Bay. It mainly inhabits shallower than 20 m in depth (Fig. 4, Tables 3, 4) but the distribution is independent of the sediments and the benthic community structures (Figs. 5–7). Type A is a coastal waters species. The density became sometimes very high. It reached 1208 individuals per m^2 at the depth of 10–15m in Osaka Bay. The density in Tosa Bay was relatively low, which was 82 individuals per m^2 at the depth of 15–20m (Table 4).

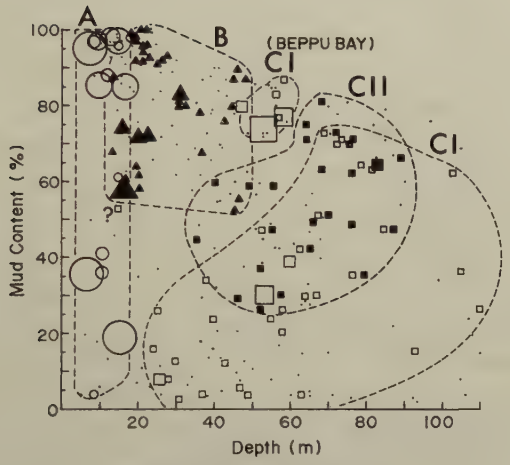


Fig. 5 Distribution of *Paraprionospio* in relation to water depth and mud content in sediment. This figure was drawn from the results of all surveys shown in Fig. 4.

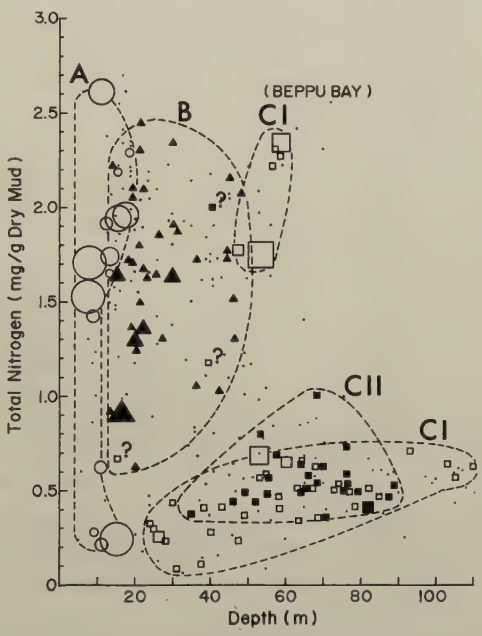


Fig. 6 Distribution of *Paraprionospio* in relation to water depth and total nitrogen in sediment. This figure was drawn from the results of all surveys shown in Fig. 4.

Table 4 Relation between water depth and mean density*1 of four types of the genus *Paraprionospio*

Depth (m)	Number of individuals/m^2													
	Type A		Type B						Type CI					Type CII
	Osaka Bay	Tosa Bay	Osaka Bay	Hiuchi-nada	Beppu Bay	Kii Channel	Tosa Bay	East China Sea	Osaka Bay	Beppu Bay	Kii Channel	Tosa Bay	East China Sea	Tosa Bay
5– 10	434.4 (9)*2	0 (19)	0 (9)	0 (3)	0 (2)		0 (19)		0 (9)	75.0 (2)		0 (19)		0 (19)
10– 15	1208.1(68)	28.4 (19)	0.3(68)	10.9 (36)			0 (19)		0(68)			0 (19)		0 (19)
15– 20	90.4(77)	82.4(143)	5.8(77)	28.8 (53)	24.3 (7)		0(143)		0.1(77)	0 (7)		1.3(143)		0(143)
20– 30	0.2(94)	0.2(122)	6.0(94)	22.7(207)	10.4(25)	10.0 (2)	0(122)		0(94)	1.2(25)	0 (2)	3.4(122)		0.3(122)
30– 40	0(62)	0 (28)	3.7(62)		7.6(51)	3.3 (3)	0 (28)		0.6(62)	0.4(51)	6.7 (3)	2.1 (28)		7.1 (28)
40– 50	0(42)	0 (28)	1.0(42)		7.3(44)	2.5 (4)	0.4(28)		1.7(42)	5.9(44)	0 (4)	3.2 (28)		7.1 (28)
50–100	0(41)	0(205)	0.2(41)		0.8(74)	0(13)	0(205)	0.7(15)	2.2(41)	45.0(74)	2.3(13)	2.0(205)	0.7(15)	10.2(205)
100–	0 (1)	0 (42)	0 (1)				0 (42)	0 (3)	0 (1)			0.7 (42)	0 (3)	0 (42)
Total	(402)	(606)	(402)	(299)	(203)	(22)	(606)	(18)	(402)	(203)	(22)	(606)	(18)	(606)

*1 Mean density was calculated from 1550 samples of 64 surveys from July 8–10, 1975 to July 8, 1981.

*2 Figure in parenthesis shows number of samplings by Smith-McIntyre grab sampler with 0.1m^2 in covering area.

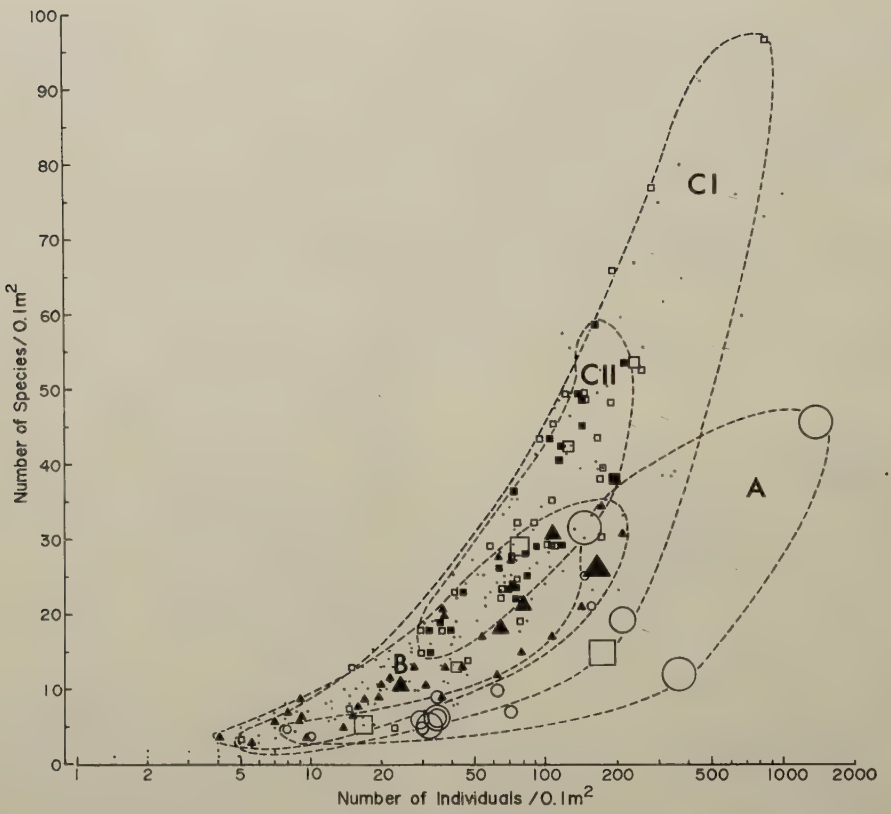


Fig. 7 Distribution of *Paraprionospio* in relation to two factors of benthic communities (number of the individuals and number of the species). This figure was drawn from the results of all surveys shown in Fig. 4.

Type B: This type was collected in all six surveyed areas but extremely rare in Tosa Bay and East China Sea (Table 3). In Hiuchi-nada, only type B was widely distribued on the organic-rich mud or muddy sand bottom and the other three *Paraprionospio* species were not sampled at all. The distributional bottom conditions of type B in Osaka Bay, Beppu Bay and Kii Channel are similar to that in Hiuchi-nada. This type is almost completely restricted to mud or muddy sand bottom containing fairly high organic matter content in inland sea region and is rarely collected in offshore waters or on sand bottom (Figs. 4-6, Table 3). In the distributional area of this type, the density of macro-benthic animals and the number of species were low or moderate (Fig. 7). The density of this type was somewhat low (Table 4).

Type CI: This type was collected in Osaka Bay, Beppu Bay, Kii Channel, Tosa Bay and East China Sea (Fig. 4, Table 3). In many cases, this type was distributed on organic-poor muddy sand or sand bottom, such as Tomogashima Strait, bay mouth of Beppu Bay, Tosa Bay, but was also collected on organic-rich mud bottom in innermost

part of Beppu Bay (Figs. 5, 6). Type CI is an eurytopic species which is able to be widely distributed in various water depth, sediments and benthic community structures. The density of this type was usually very low except the case of Beppu Bay (Table 4).

Type CII: Type CII is an offshore waters species, which was collected only in Tosa Bay and not collected in inland sea region at all (Fig. 4, Table 3). This type was almost distributed on muddy sand bottom with low organic matter content at depths deeper than 35m (Figs. 5, 6). Benthic fauna in the distributional area of this type was fairly rich (Fig. 7). The density of this type was low (Table 4).

The distributional characters of each type are summarized as Table 5.

Table 5 Comparison among the distributional area of four types of the genus *Paraprionospio*

	Type A	Type B	Type CI		Type CII
			innermost part of Beppu Bay	the others	
	coastal waters species	inland sea species	eurytopic species		offshore waters species
Distributional area	Osaka Bay (1396)*1 Tosa Bay (1021)	Osaka Bay (21) Hiuchi-nada (688) Beppu Bay (120) Kii Channel (4) Tosa Bay (1) East China Sea (1)	Beppu Bay (332)	Osaka Bay (21) Beppu Bay (47) Kii Channel (5) Tosa Bay (98) East China Sea (1)	Tosa Bay (194)
Depth range	shallower than 20m	10–54m	26–60m	8–110m	25–98m
Sediments*2	GS–M	MS–M	M	S–MS	MS
Organic matter content in sediments	low-high	moderate-high	high	low	low
Benthic community					
Density	low-high	low-moderate	low-moderate	moderate-high	moderate
Number of species	low-high	low-moderate	low	moderate-high	moderate-high

*1 Number of the collected specimens
*2 See Table 3

IV Life history of the four types of *Paraprionospio* and seasonal changes in benthic community

In this chapter, oceanographic environment and benthic community structure were studied seasonally in Osaka Bay, Hiuchi-nada and Tosa Bay. The life history of the four types of *Paraprionospio* were also investigated in these areas. Osaka Bay and Hiuchi-nada are inland sea areas and Tosa Bay is an open bay strongly influenced by the Kuroshio. The life history of type A was investigated in Osaka Bay and Tosa Bay. The life history of type B was investigated in Osaka Bay and Hiuchi-nada. The life histories of types CI and CII were examined in Tosa Bay.

IV-1 Methods

Sampling areas were shown in Fig. 8. The surveys in Osaka Bay were carried out fifteen times throughout the year from April 18, 1979 to March 9, 1980. Five sampling

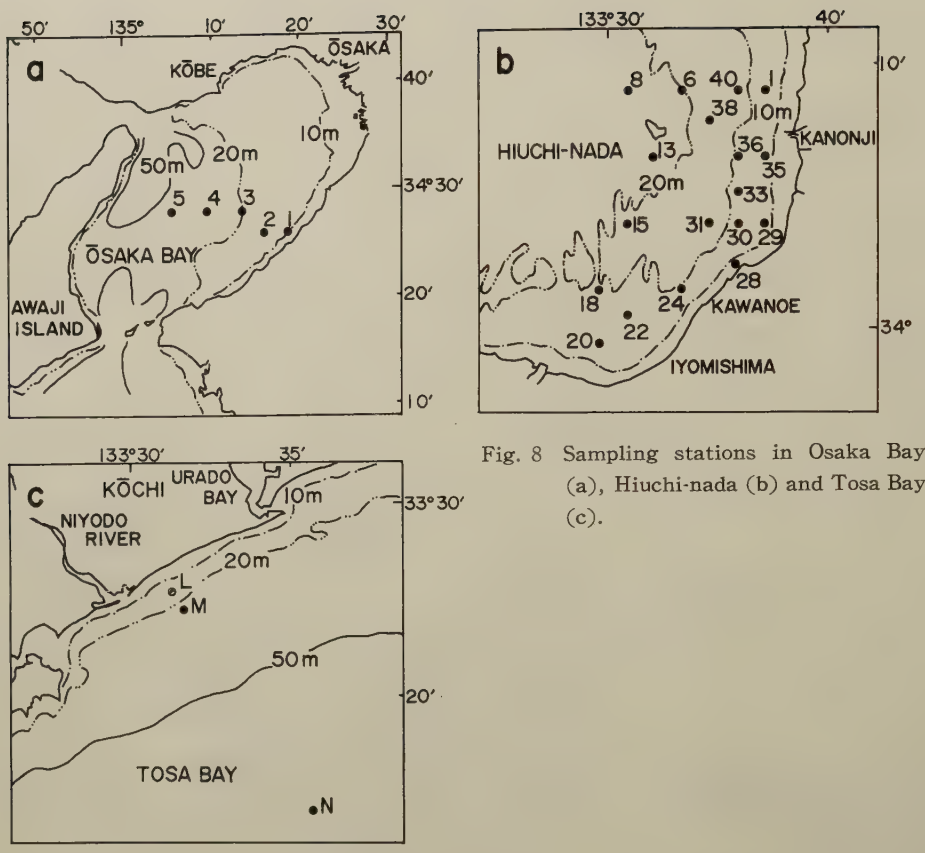


Fig. 8 Sampling stations in Osaka Bay (a), Hiuchi-nada (b) and Tosa Bay (c).

stations, Stns. 1-5 were arranged in order of water depth. The depth of each station was 10m, 15m, 20m, 28m and 39m. The surveys in Hiuchi-nada were carried out eleven times throughout about four years from August 4-5, 1977 to June 23-24, 1981. The depth range of sampling stations was 8-26m. The surveys in Tosa Bay were carried out twenty nine times throughout longer than the four years from February 16-17, 1977 to July 8, 1981 at Stns. L and M, and twenty times throughout longer than the two years from April 26, 1979 to July 8, 1981 at Stn. N. The water depths were 15m at stn. L, 25m at Stn. M and 80m at Stn. N.

Physico-chemical factors usually measured were as follows: temperature, salinity and dissolved oxygen in both surface and bottom water; temperature, total carbon content, total nitrogen content, ignition loss and mud content in sediment. Ignition loss was estimated from the loss of weight on ignition at 850°C for 1 hour of dried sediment samples from which coarse particles were previously removed by 1mm mesh sieve. The methods for measurement of the other environmntal factors are as described in chapter III.

Smith-McIntyre grab sampler was used to collect macrobenthic animals and sediments.

In Osaka Bay, three samples were taken at Stn. 1 and two samples at the others. In Hiuchi-nada, one to five samples were collected at each station. In Tosa Bay, two to five samples were collected at each station. Collected samples were sieve by a 1mm mesh sieve, and the animals retained on the sieve were fixed by formalin. 0.5mm mesh was also put under 1mm mesh to collect the juveniles of *Paraprionospio* effectively in May 27-28, 1979 and after December 13-14, 1979 in Hiuchi-nada, and after December 18, 1978 in Tosa Bay. The density of macrobenthic animals and the percentage composition of *Paraprionospio* were calculated from the specimens collected with 1mm mesh sieve.

The most convenient parameter of worm size is the body width since many worms were incomplete due to the loss of rear end during collection. Width of the fifth setiger excluding parapodia of all worms, and total length, wet weight and number of setigers of some complete worms were measured. All *Paraprionospio* specimens collected were used for size frequency analyses regardless of the sieve mesh sizes to collect benthic animals.

Presence of the gametes in coelom was examined microscopically. The total number of eggs per worm was estimated by the following procedures. All eggs in coelom of the complete female fully suspended in 50cc of tap water, and three subsamples of 1cc were taken. The number of eggs in each subsample was counted under a microscope, and the mean value obtained from the three subsamples was used to calculate the total number of eggs per worm. No complete females of type B containing eggs were obtained, so the total number of eggs of this type could not be calculated. Egg diameter was shown by the mean value of the longest and shortest diameter measured using a microscope with a micrometer. The diameter of twenty eggs per female was measured and five females were examined per survey, if possible. Namely, the diameter of one hundred eggs per survey was usually measured.

The brief ecological observations of type A were carried out in the laboratory. Type A for this observation was collected at Stn. L in Tosa Bay in February 9, 1982. The worms were reared in acrylic tube of 40mm in diameter and 200mm in length containing the sediment and the sea water of sampling station. They were observed under the aeration and temperature regulation.

IV-2 Seasonal changes in bottom environments and benthic community structures

Osaka Bay

Bottom environments: Fig. 9 shows the seasonal changes in temperature, salinity and dissolved oxygen in bottom water at Stns. 1-5. The minimum temperatures were 7. 3-9.1°C from February to March and the maximum temperatures reached 23.5-24.8°C

from August to September. The salinity ranged from 31.25 to 33.83‰ at all stations throughout the year, slightly influenced by fresh water. The salinity was somewhat higher in warm season than in cold season. The dissolved oxygen concentration became low in varying extent during June to September at all stations. At Stns. 1-2, dissolved oxygen content fell below 40% in saturation from August to September, at Stn. 3 it was more than 50% except in early June showing 43%, and at Stns. 4-5 it was more than 60% throughout the year. In this area, the dissolved oxygen concentration became high

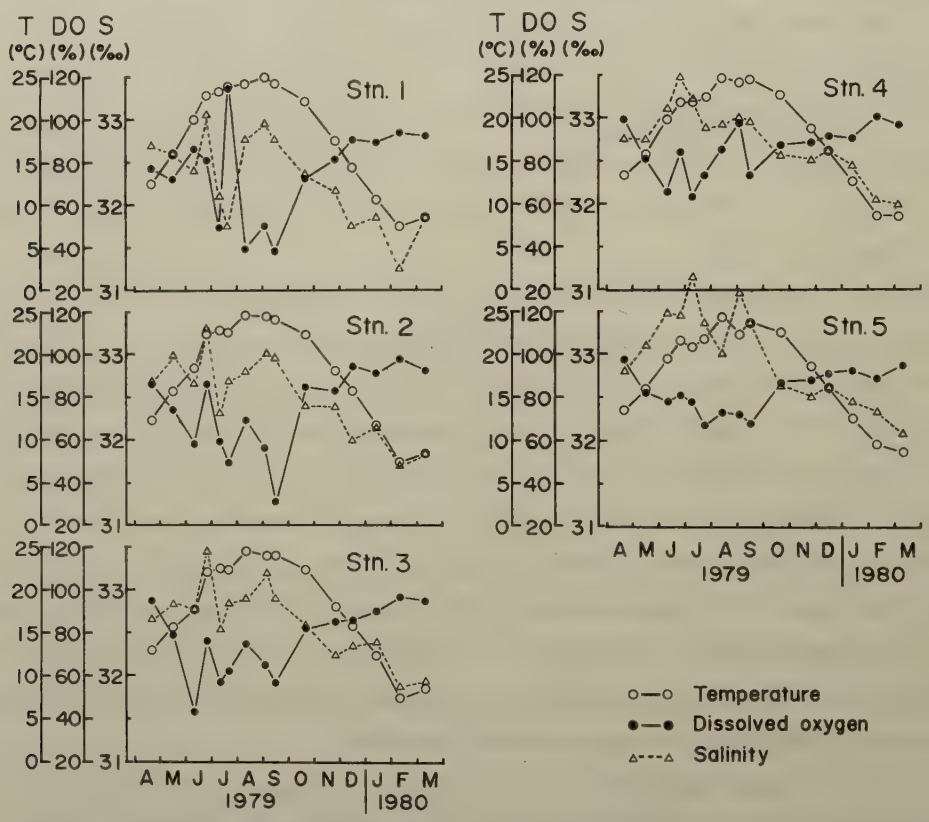


Fig. 9 Seasonal changes in temperarure, dissolved oxygen and salinity in bottom water in Osaka Bay from April 18, 1979 to March 9, 1980.

Table 6 Physico-chemical characters of sediments collected at stations 1–5 in Osaka Bay on March 9, 1980.

Station	Total carbon (mg/g dry mud)	Total nitrogen (mg/g dry mud)	Ignition loss (%)	Mud content (%)
1	2.77	0.30	2.7	10.9
2	21.17	2.23	11.3	98.8
3	22.65	2.17	11.2	98.8
4	17.34	1.48	8.8	75.5
5	18.58	0.99	7.6	47.3

with increasing water depth.

Physico-chemical characters of sediments are presented in Table 6. The bottom of Stn. 1 was occupied mainly by sand, shell and gravel with a small amount of organic matter, because of the influence of wave action. On the contrary, the bottom of Stns. 2-3 was almost completely occupied by the organic matter-rich, soft mud. This fact suggests that water currents above the bottom are very gentle. The bottom of Stns. 4-5 was covered with muddy sand. The organic matter content showed the moderate value.

On the basis of the nature of bottom water and sediment described above, these five stations can be divided into three groups, namely, Stn. 1, Stns. 2-3 and Stns. 4-5.

Table 7 Annual means of density and number of species of the macrobenthic animals at stations 1-5 in Osaka Bay from April 18, 1979 to March 9, 1980.

A) Density

Taxonomic group	Stn. 1		Stn. 2		Stn. 3		Stn. 4		Stn. 5	
	Ind./m²	%	Ind./m²	%	Ind./m²	%	Ind./m²	%	Ind./m²	%
Polychaeta	5756	90.7	357	89.1	54	61.4	142	53.0	168	59.7
Crustacea	107	1.7	10	2.4	11	12.6	10	3.6	18	6.5
Echinodermata	57	0.9	7	1.8	9	10.3	14	5.2	39	13.7
Mollusca	218	3.4	21	5.2	10	11.1	86	32.1	32	11.2
Others	211	3.3	6	1.5	4	4.6	16	6.1	25	8.9
Total	6349		401		87		269		282	

B) Number of species

Taxonomic group	Stn. 1		Stn. 2		Stn. 3		Stn. 4		Stn. 5	
	No./0.1m²	%	No./0.1m²	%	No./0.1m²	%	No./0.1m²	%	No./0.1m²	%
Polychaeta	18.8	65.1	6.4	71.0	3.5	62.1	6.9	57.2	8.3	62.9
Crustacea	2.5	8.6	0.5	5.2	0.6	11.6	0.9	7.8	1.3	10.1
Echinodermata	0.5	1.9	0.4	4.8	0.5	9.8	1.0	8.3	1.1	8.1
Mollusca	3.0	10.6	1.1	12.3	0.7	12.8	1.9	16.1	1.3	9.8
Others	4.0	13.8	0.6	6.7	0.2	3.7	1.3	10.6	1.2	9.1
Total	28.8		9.0		5.5		12.0		13.2	

Benthic community: Density, number of species and their seasonal changes are shown in Table 7 and Fig. 10. Seasonal changes in main component species of each station are shown in Fig. 11 and Appendix table 1.

At Stn. 1, number of species and density of the benthic animals were the highest of all five stations. Polychaetes were numerically most abundant. There were two peaks of the density of benthic animals, one is from June to July and the other from

September to October. The lower density was found from November to April. The peak from June to July was composed of the polychaetes *Euchone* sp., *Pseudopolydora* sp., amphipod *Corophium acherusicum* and so on, and the next peak was composed of two dominant polychaete species, *Paraprionospio* sp. (type A) and *Cirriformia tentaculata*. Polychaetes *Lumbrineris longifolia*, *Sigambra tentaculata* and *Glycinde* sp. were fairly abundant and common throughout the year. Number of species was very

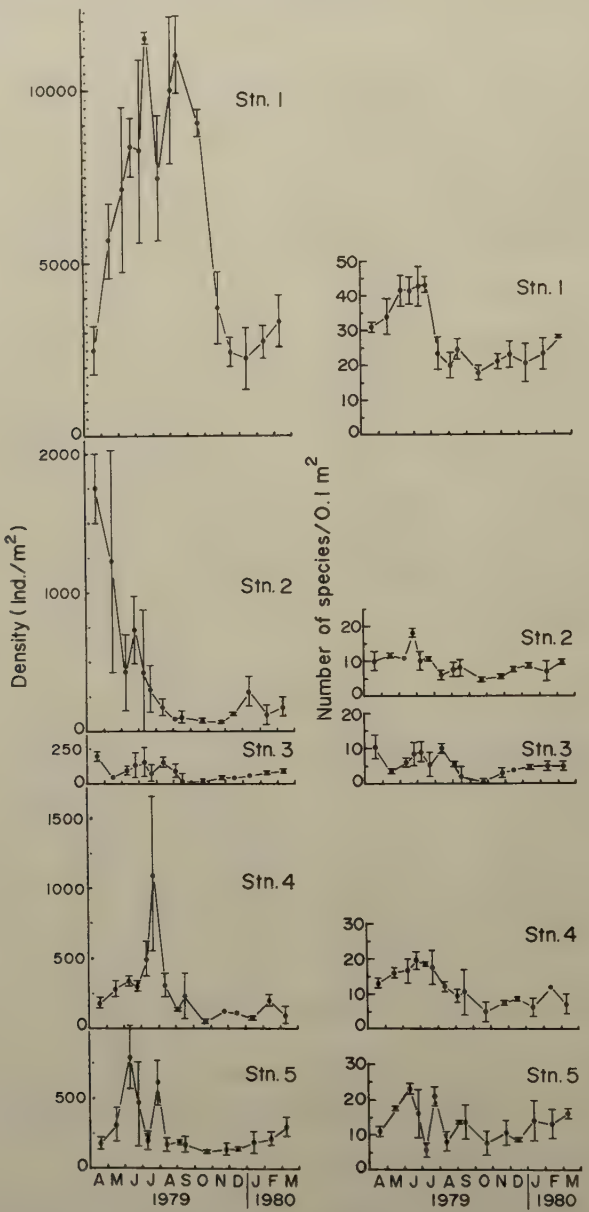


Fig. 10 Seasonal changes in density and species number of macrobenthic animals in Osaka Bay from April 18, 1979 to March 9, 1980. Closed circle shows mean value and vertical bar shows standard deviation.

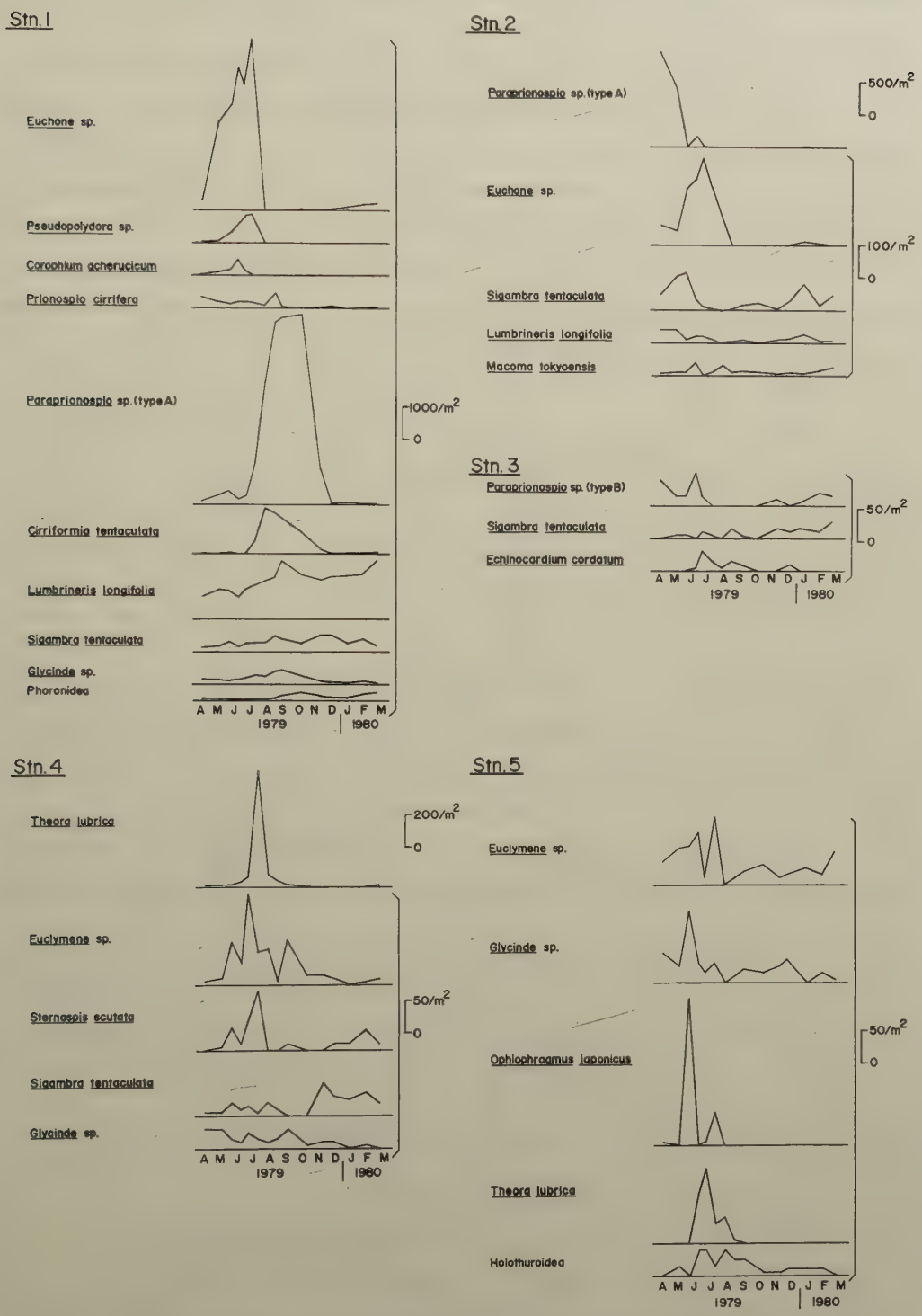


Fig. 11 Seasonal changes in density of numerically abundant species in Osaka Bay from April 18, 1979 to March 9, 1980.

high during early June to late July, and immediately after, the rapid decrease of species number followed.

Stn. 2 is characterized by the dominant occurrence of *Paraprionospio* sp. (type A). Type A occupied about half of the total number of specimens collected at Stn. 2. Density of the benthic animals was high in spring, and low in fall. This spring peak was composed of type A. Number of species was slightly high from spring to summer and low in fall. Annual mean number of species was low.

Benthic fauna of Stn. 3 was very poor. Number of species and density of benthic animals were slightly high from spring to summer, and low in fall. Species collected more than 20 individuals were only two polychaete species, *Paraprionospio* sp. (type B) and *Sigambra tentaculata*.

Stn. 4 and Stn. 5 resemble each other in benthic structure. Density and number of species of both stations were 270-280 individuals per m^2 and 12-13 per $0.1m^2$ respectively, and they were high in summer and low in fall. The main component species of both stations were bivalve mollusc *Theora lubrica*, polychaetes *Euclymene* sp., *Sternaspis scutata*, *Sigambra tentaculata* and *Glycinde* sp..

Hiuchi-nada

Bottom environments: As the bottom water and sediments in this area change with water depth, this area was conveniently divided into two parts by the 15m depth contour. Environmental factors showing the remarkable change with water depth were dissolved oxygen in bottom water and several sediment factors (Table 8). Oxygen deficiency in bottom water was conspicuous at the depth more than 15m. The mean dissolved oxygen in saturation at the depth more than 15m fell below 40% in August, while in the shallower region it was maintained above 70%. The sediment factors such as mud content, total nitrogen content and total carbon content were all high on

Table 8 Physico-chemical characters of bottom water and sediments in Hiuchi-nada.

	Water depth (m)	Range or mean ± standard deviation
Dissolved oxygen (%)	-15	71.7±22.8 (August) 107.2±11.3 (the others)
	15-	37.5±18.7 (August) 100.7±15.6 (the others)
Salinity (‰)	-15	32.31±0.08
	15-	32.47±0.17
Mud temperature (°C)	-15	8.1 (February)−25.9 (August)
	15-	8.9 (February)−24.9 (August)
Total carbon (mg/g dry mud)	-15	9.18±4.69
	15-	16.91±2.77
Total nitrogen (mg/g dry mud)	-15	0.63±0.31
	15-	1.80±0.37
Mud content (%)	-15	31.9±22.7
	15-	78.9±17.0

mud bottom deeper than 15m in depth. The bottom shallower than 15m was occupied by sand or muddy sand, and the values of each sediment factor were low.

Benthic community: Density and number of species are shown in Table 9, their seasonal changes shown in Fig. 12, and seasonal changes in main component species shown in Table 10.

At the depth shallower than 15m, density and number of species were much higher than in the deeper region. Polychaete and crustacean were numerically abundant groups. High density and high percentage composition in density of crustacean were mainly caused by the large number of amphipod *Corophium* sp. specimens in June 6–7, 1978.

Table 9 Means of density and number of species of the macrobenthic animals in Hiuchi-nada from August 4–5, 1977 to June 23–24, 1981.

A) Density

Taxonomic group	Shallower than 15m		Deeper than 15m	
	Ind./m²	%	Ind./m²	%
Polychaeta	1339	52.7	140	54.8
Crustacea	805	31.7	7	2.5
Echinodermata	153	6.0	11	4.2
Mollusca	190	7.5	92	35.5
Others	53	2.1	8	3.0
Total	2540		258	

B) Number of species

Taxonomic group	Shallower than 15m		Deeper than 15m	
	No./0.1m²	%	No./0.1m²	%
Polychaeta	18.1	70.0	4.3	63.6
Crustacea	2.4	9.4	0.5	6.4
Echinodermata	1.0	3.8	0.4	5.0
Mollusca	2.6	10.0	1.3	18.4
Others	1.7	6.8	0.5	6.6
Total	25.8		7.0	

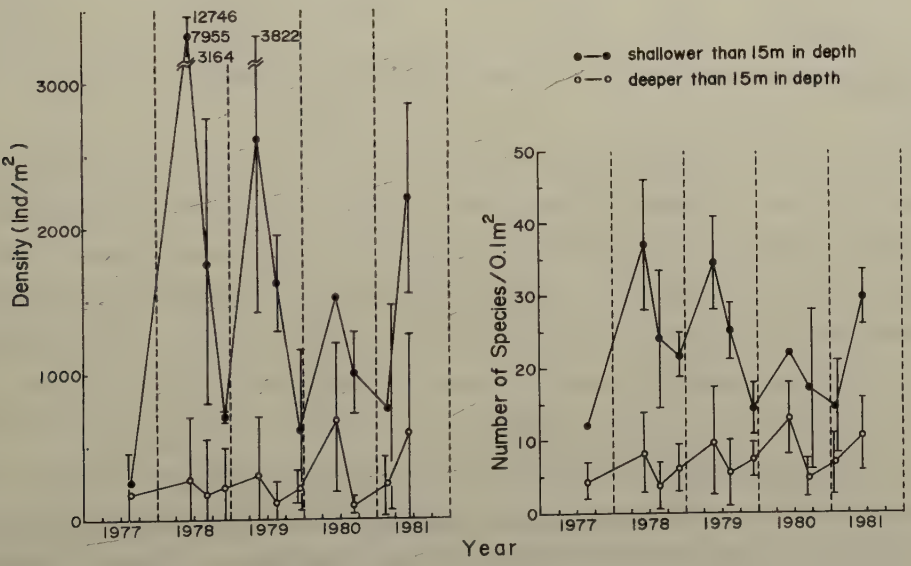


Fig. 12 Seasonal changes in density and species number of macrobenthic animals in Hiuchi-nada from August 4–5, 1977 to June 23–24, 1981. Closed and open circles show mean value and vertical bar shows standard deviation.

Table 10 Density (Ind./m²) of numerically abundant species in Hiuchi-nada from August 4–5, 1977 to June 23–24, 1981.

Region	Rank	Scientific name	Taxonomic group	1977	1978			1979			1980		1981		Mean	Cumulative Percentage
				Aug. 4, 5	June 6, 7	Aug. 28, 29	Nov. 30	May 27, 28	Aug. 22, 23	Dec. 13, 14	June 11, 12	Aug. 31 Sept. 1	Feb. 3–5	June 23, 24		
	1	*Corophium* sp.	Cr		4840.0	27.8		12 5	3.3						444.0	23.35
	2	*Lumbrineris longifolia*	P	70.0	260.0	641.0		587.5	591.7	225.0	480.0	490.0	305.0	353.3	364.0	42.49
	3	*Lygdamis* sp.	P		756.7	176.7		392.5				46.7			124.8	49.05
	4	*Theora lubrica*	M	10.0	196.7			290.0	35.0		200.0	6.7		376.7	101.4	54.38
	5	*Prionospio ehlersi*	P		18.3	12.2		122.5	65.0	95.0	460.0	20.0	90.0	163.3	95.1	59.38
	6	Ophiuroidea sp.	E		603.3	44.4		90.0	1.7			93.3			75.7	63.36
	7	*Prazillella affinis*	P		91.7	323.3	30.0	105.0	218.3		10.0			23.3	72.9	67.19
	8	*Raeta rostralis*	M		26.7						20.0			423.3	42.7	69.44
	9	Nemertinea sp.	N	10.0	48.3	4.4	100.0	35.0	30.0	20.0	20.0	23.3	25.0	66.7	34.8	71.27
	10	*Notomastus* sp.	P	40.0	46.7	47.8		17.5	30.0	75.0	10.0		20.0	6.7	26.7	72.67
15m>	11	*Sigambra tentaculata*	P		28.3	21.1		42.5	36.7	15.0	30.0	16.7		36.7	20.6	73.75
	12	*Nephtys Polybranchia*	P	30.0	15.0	8.9	5.0	27.5	1.7		100.0	3.3		26.7	19.8	74.79
	13	*Pseudopolydora* sp.	P		13.3	6.7			6.7	10.0	20.0	6.7	20.0	126.7	19.1	75.79
	14	*Poecilochaetus japonicus*	P		11.7	11.1	5.0	52.5	43.3	30.0		13.3	30.0	3.3	18.2	76.75
	15	Holothuroidea sp.	E	10.0	8.3			12.5	151.7			3.3		6.7	17.5	77.67
	16	*Harmothoe imbricata*	P		115.0	1.1		62.5				13.3			17.4	78.59
	17	*Euchone* sp.	P		65.0			10.0		5.0				110.0	17.3	79.50
	18	*Lagis bocki*	P		170.0			12.5							16.6	80.37
	19	*Chaetozone* sp.	P		1.7	64.4		2.5			10.0	23.3	65.0	13.3	16.4	81.23
	20	*Tharyx* sp.	P		30.0	57.8		40.0	3.3			36.7			15.3	82.03
		(*Paraprionospio* sp. (type B))	P	10.0		2.2		12.5	1.7	5.0	10.0	10.0	25.0	43.3	10.9	
	1	*Theora lubrica*	M	109.0	65.6	46.0	1.4	49.4	7.3	4.7	308.8	2.0	12.1	146.7	68.5	24.56
	2	*Paraprionospio* sp. (type B)	P	0.6	1.0	1.4	42.7	18.8	10.7	24.0	17.1	1.3	83.6	62.0	23.9	33.13
	3	*Raeta rostralis*	M					0.3			1.8			224.7	20.6	40.52
	4	*Lumbrineris longifolia*	P	9.0	42.6	64.3	6.4	9.4	5.7		56.5	4.0	5.7	2.7	18.8	47.26
	5	*Prionospio ehlersi*	P		3.8	0.3	29.5	25.3	9.3	6.0	57.6	0.7	33.6	8.0	15.8	52.93
	6	*P. cirrifera*	P		4.4	2.9	1.4	9.4	3.7	73.3	16.5	16.7	7.9	8.0	13.1	57.63
	7	*Sigambra tentaculata*	P	3.2	24.4	4.3	10.9	20.6	8.7	4.0	20.0	13.3	6.4	4.7	11.0	61.57
	8	*Sthenolepis yhleni*	P		1.0	1.4	7.3	13.4	1.3	36.7	20.0	5.3	8.6	1.3	8.8	64.73
	9	*Notomastus* sp.	P	18.7	20.5	9.1	10.9	11.6	6.0	3.3	3.5	3.3	6.4	1.3	8.6	67.81
15m≦	10	*Nephtys Polybranchia*	P	1.6	6.7	6.9	0.5	6.6	4.0	1.3	18.8		12.1	22.7	7.4	70.46
	11	*Pseudopolydora* sp.	P		2.6	0.6	46.4	0.6	0.7	4.0			5.7	20.0	7.3	73.08
	12	*Zeuxis squinjoreusis*	M	0.3	1.3	12.6	9.1	2.8	3.0	2.7	11.2	3.3	10.0	4.7	5.5	75.05
	13	Nemertinea sp.	N	1.9	8.5	0.9	2.3	8.4	2.0	6.7	10.6	2.7	5.0	10.0	5.4	76.99
	14	Holothuroidea sp.	E	9.7	4.6	2.3		35.6	2.7	2.7				0.7	5.3	78.89
	15	*Spiochaetopterus costarum*	P	2.9	3.1	0.6	20.5	3.8	3.0	8.0	1.8			2.0	4.2	80.40
	16	*Yokoyamaia ornatissima*	M		12.3	2.3		14.4		0.7	4.7	0.7	0.7	8.0	4.0	81.83
	17	*Poecilochaetus japonicus*	P		5.1	0.6		10.9	5.7		5.3			6.0	3.1	82.94
	18	*Micronephtys* sp.	P					1.6		0.7	27.6		3.6	0.7	3.1	84.04
	19	*Cossura coasta*	P					5.9	0.7		18.2	1.3		1.3	2.5	84.95
	20	Ophiuroidea sp.	E	10.0	1.0	0.9	0.9		6.7	0.7	5.3				2.3	85.77

Taxonomic groups are abbreviated as: Cr; Crustacea, E; Echinodermata, M; Mollusca, N; Nemertinea, P; Polychaeta.

Density and number of species were high during May to June and low during late summer to winter. *Corophium* sp., polychaetes *Lumbrineris longifolia* and *Lygdamis* sp. and mollusc *Theora lubrica* showed relatively high mean density greater than 100 individuals per m². Density of *Lumbrineris longifolia* was fairly stable and showed 225–640 individuals per m² except in August, 1977 and November, 1978. *Theora lubrica* and *Lygdamis* sp. were abundant in early summer, and were rare in fall and winter.

At the depths more than 15m, benthic fauna was poor. Density was one-fifteenth as high as at the depths less than 15m, and the number of species was about one-fourth. Numerically abundant animal groups were polychaete and mollusc. Seasonal changes in density and number of species in this region were very similar to those in shallower region. They were high during May to June, and low during summer to winter. *Theora lubrica*, *Paraprionospio* sp. (type B) and *Lumbrineris longifolia* were common in

this region, but not abundant. Type B was the typical species which was more abundant on deep mud bottom than on shallow sand or muddy sand bottom. Such species were rare in this region.

Tosa Bay

Bottom environments: Fig. 13 shows the seasonal changes in temperature, salinity and dissolved oxygen concentration in bottom water. Temperature was fairly high and ranged from 14.7 to 26.9°C at Stn. L, from 14.9 to 26.0°C at Stn. M and from 16.1 to 22.2°C at Stn. N. Differences between minimum and maximum temperature at all stations were fairly small, especially the difference at Stn. N was only 6.1°C, which was half as large as those at Stns. L and M. Salinity showed high value ranging from

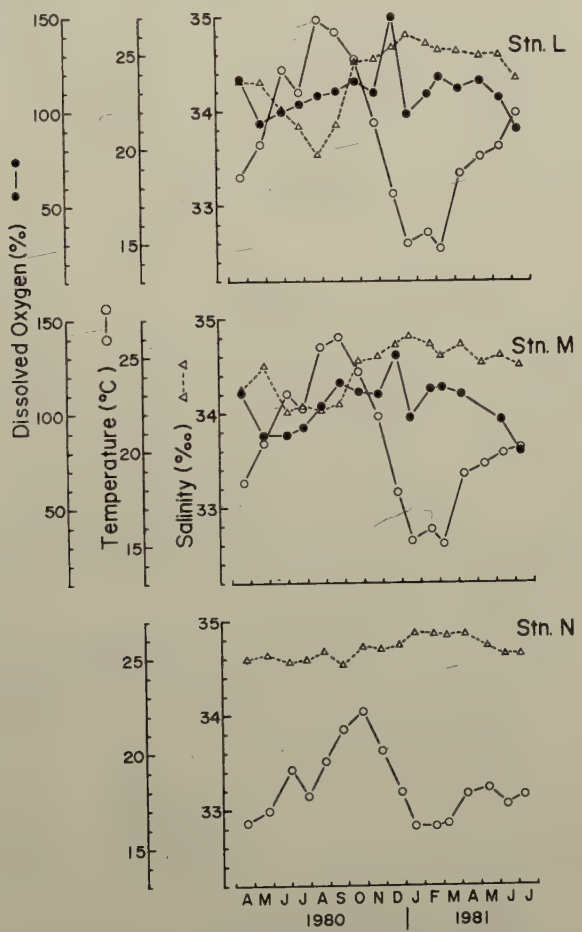


Fig. 13 Seasonal changes in temperature, dissolved oxygen and salinily in bottom water in Tosa Bay from April 22, 1980 to July 8, 1981. Dissolved oxygen at Stn. N was not measured.

33.5 to 35‰ throughout all surveys at all stations. Dissolved oxygen was 91-150% in saturation at Stn. L, and 79-130% at Stn. M. Dissolved oxygen at Stn. N was not measured. It was, however, suggested that oxygen deficiency took place only very weakly also at Stn. N if any because bottom sediments collected at this station were grayish brown in color and a sulfide odor was not noted at all. In summary, bottom water environments in this area was characterized by relatively stable and high temperature, salinity and dissolved oxygen concentration.

Table 11 shows the bottom sediment characters at these three stations. At Stns. L and M, mud content and organic matter content were very low. The bottom was occupied by sand. At Stn. N, mud content and organic matter content were a little

Table 11 Physico-chemical characters of sediments collected at stations L, M, N in Tosa Bay from April 22, 1980 to July 28, 1981. Mean ± standard deviation.

Station	Total carbon (mg/g dry mud)	Total nitrogen (mg/g dry mud)	Ignition loss (%)	Mud content (%)
L	1.85±0.69	0.23±0.08	3.5±0.4	9.8± 7.8
M	3.54±1.60	0.34±0.11	—	21.5±14.9
N	7.33±0.73	0.50±0.06	—	58.8± 4.3

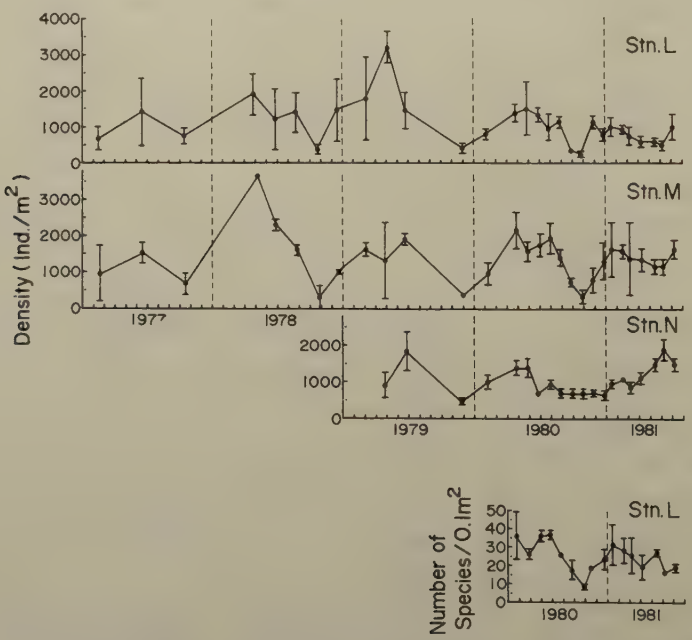


Fig. 14 Seasonal changes in density and species number of macrobenthic animals in Tosa Bay. Surveys were not carried out before April 26, 1979 at Stn. N. Identification was performed after April 22, 1980 only at Stn. L. Closed circle shows mean value and vertical bar shows standard deviation.

higher than at Stns. L and M. The bottom sediment at Stn. N consisted of muddy sand.

Benthic community: The mean density and number of species are shown in Table 12, their seasonal changes shown in Fig. 14, and seasonal changes in main component species shown in Fig. 15. Identifications of benthic animals were performed only at Stn. L after April 22, 1980.

Table 12 Means of density and number of species of the macrobenthic animals in Tosa Bay.

A) Density (February 16–17, 1977–July 8, 1981)

Taxonomic group	Stn. L		Stn. M		Stn. N	
	Ind./m²	%	Ind./m²	%	Ind./m²	%
Polychaeta	395	37.2	661	48.2	582	56.5
Crustacea	295	27.8	457	33.4	191	18.5
Echinodermata	7	0.6	27	2.0	33	3.2
Mollusca	314	29.6	152	11.1	30	2.9
Others	51	4.8	72	5.3	194	18.9
Total	1062		1369		1030	

B) Number of species (April 22, 1980–July 8, 1981)

Taxonomic group	Stn. L	
	No./0.1m²	%
Polychaeta	8.7	35.2
Crustacea	8.2	33.5
Echinodermata	0.4	1.8
Mollusca	5.9	24.2
Others	1.3	5.3
Total	24.5	

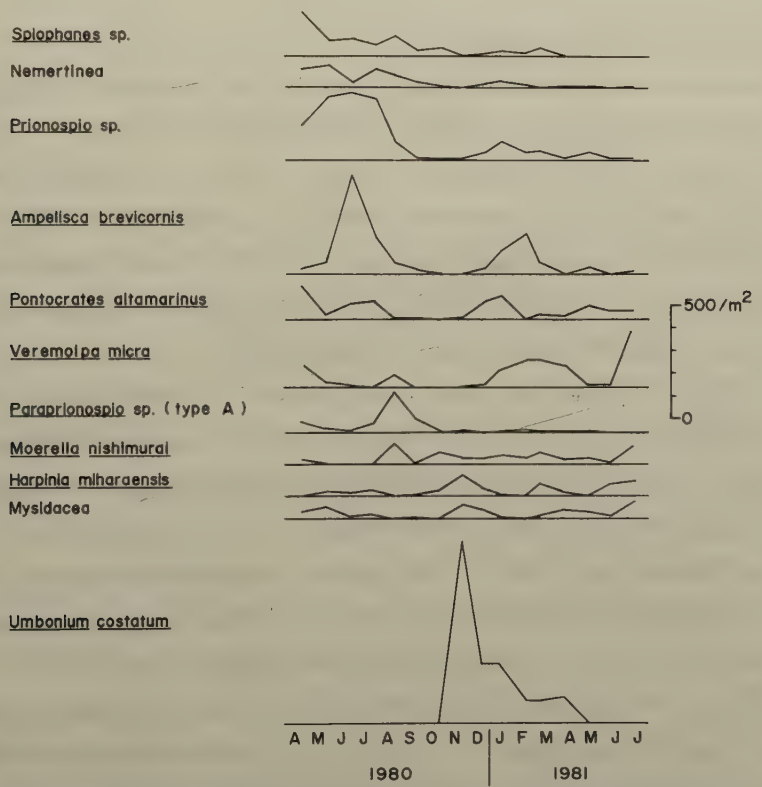


Fig. 15 Seasonal changes in density of numerically abundant species at Stn. L in Tosa Bay from April 22, 1980 to July 8, 1981.

At Stn. L, mean density of the benthic animals was fairly high, and polychaete, crustacean and mollusc were numerically abundant groups. Mean number of species was 24.5 per 0.1m^2. The density and number of species of benthic animals changed seasonally. They were high from spring and low in fall. Snail *Umbonium costatum*, polychaete *Prionospio* sp. and crustacean *Ampelisca brevicornis* were numerically abundant species. *Umbonium costatum* was collected from late November to early April. The other species did not show the apparent periodical seasonal changes.

Mean density of the benthic animals at Stn. M was the highest of these three stations, and polychaete and crustacean were abundant. The seasonal change in density at this station is similar to that at Stn. L.

Mean density of the benthic animals at Stn. N is approximately equal to that at Stn. L. Percentage composition of polychaete in density was about 57% and that of crustacean was about 19%. Density of benthic animals was relatively high in spring and slightly low from fall to winter.

Benthic communities in this area are characterized by relatively high density of benthic animals, high percentage of crustaceans in density and probably a large number of species.

Eutrophic stages of surveyed area

Benthic communities are qualitatively and quantitatively influenced by the eutrophication. In general, three stages have been recognized with distance from sources of organic input, namely, abiotic, polluted and normal stage, and in many cases, hypertrophic stage has been also found between polluted and normal stage (REISH, 1955, 1973; KITAMORI, 1966, 1970; PEARSON and ROSENBERG, 1976, 1978; DAUER and CONNER, 1980). But these four stages are not always arranged in order of abiotic, polluted, hypertrophic and normal from sources of organic input. KITAMORI (1970) illustrated the changes in abundance, number of species and ratio of abundance to number of species along a gradient of increasing organic matter. PEARSON and ROSENBERG (1978) showed the general outline of number of species, abundance and biomass along a gradient of organic enrichment, The outline was named SAB diagram by the capital letters of species, abundance and biomass. According to their studies, in abiotic stage, organic pollution is very severe and there are no macrobenthic animals. Polluted stage is largely influenced by organic pollution and is characterized by low biomass, low density, low species number and low species diversity, or by flourishes of a few very tolerant species. In hypertrophic stage, biomass, density, number of species and species diversity are all high. In normal stage, biomass, density and number of species are usually a little lower than in hypertrophic stage. Species diversity in this stage is approximately as high

as that in hypertrophic stage.

Table 13 gives the outline of bottom environments and benthic communities of the surveyed areas—Osaka Bay, Hiuchi-nada and Tosa Bay. Judging from the benthic communities and bottom environments, eutrophic stage of each surveyed stations or areas is thought to be as follows;

Table 13 Bottom environments and benthic communities in Osaka Bay, Hiuchi-nada and Tosa Bay

	Osaka Bay					Hiuchi-nada		Tosa Bay		
	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	15m>	15m≦	Stn. L	Stn. M	Stn. N
Depth (m)	10	15	20	28	39	15>	15≦	15	25	80
Bottom water										
Temperature (℃)	7.3-24.8	7.5-24.5	7.6-24.5	8.4-24.5	8.6-24.3	8.1-25.9*1	8.9-24.9*1	14.7-26.9	14.9-26.0	16.1-22.2
Salinity (‰)	31.25-33.04	31.70-33.31	31.88-33.44	31.97-33.46	32.07-33.87	32.21-32.45	32.27-32.90	33.56-34.80	33.99-34.82	34.54-34.88
Dissolved oxygen (%)	38-114	31-97	43-97	63-100	67-98	53-117	20-124	91-150	79-130	—
Sediments										
Total carbon (mg/g dry mud)	2.77	21.17	22.65	17.34	18.58	9.18	16.91	1.85	3.54	7.33
Total nitrogen (mg/g dry mud)	0.30	2.23	2.17	1.48	0.99	0.63	1.80	0.23	0.34	0.50
Ignition loss (%)	2.7	11.3	11.2	8.8	7.6	—	—	3.5	—	—
Mud content (%)	10.9	98.8	98.8	75.5	47.3	31.9	78.9	9.8	21.5	58.8
Benthic community										
Biomass (g/m²)	53.3	9.2	3.3	8.2	9.0	61.4	7.1	7.7	19.2	14.0
Density (ind./m²)	6349	401	87	269	282	2540	258	1062	1369	1030
No. of species/0.1m²	28.8	9.0	5.5	12.0	13.2	25.8	7.0	24.5	—	—
Composition in density (%)										
Polychaeta	90.7	89.1	61.4	53.0	59.7	52.7	54.8	37.2	48.2	56.5
Mollusca	3.4	5.2	11.1	32.1	11.2	7.5	35.5	29.6	11.1	2.9
Crustacea	1.7	2.4	12.6	3.6	6.5	31.7	2.5	27.8	33.4	18.5
Diversity (H')*2	2.73	2.41	2.26	3.05	3.27	3.04	2.01	3.68	—	—

Range or mean was shown.

*1 Mud temperature.

*2 $H' = -\sum_{i=1}^{s} \frac{n_i}{N} \log_2 \frac{n_i}{N}$ Where n_i is the number of individuals of the i-th species, N is the total number of individuals, and s is the total number of species.

abiotic stage...no stations

polluted stage...Stns. 2, 3 (Osaka Bay), deeper than 15m (Hiuchi-nada)

hypertrophic stage...Stn. 1 (Osaka Bay), shallower than 15m (Hiuchi-nada)

normal stage...Stns. 4, 5 (Osaka Bay), Stns. L, M, N (Tosa Bay)

Stns. 2, 3 in Osaka Bay and the area deeper than 15m in Hiuchi-nada are undoubtedly assigned to polluted stage. In these areas, number of the species and species diversity were both low, oxygen deficiency occurred strongly, organic matter content in sediment was high. Stn. 1 in Osaka Bay and the area shallower than 15m in Hiuchi-nada are thought to be hypertrophic stage. Organic matter content in sediment was low but dissolved oxygen in bottom water fell to about 40-50% in saturation. The biomass and density of benthic animals were very high and the species number was high. The low oxygen content, high biomass and high density show the presence of the influx of a large amount of organic matter into its water mass. Such organic matter is mainly derived from organic-rich fresh water and supports high biomass and high density of benthic animals. Stn. L in Tosa Bay is apparently normal stage. Dissolved oxygen

deficiency of bottom water did not happen and the organic matter content in sediment was low. The number of species and species diversity were high, the density of macrobenthic animals was fairly high and the biomass was low. It seems to be suitable that Stns. 4, 5 in Osaka Bay are also treated as normal stage in spite of rather low density and species number of benhtic animals. In these stations, the fall in dissolved oxygen concentration was small, organic matter content in sediment was not so high, species diversiry was fairly high. Stns. L, M in Tosa Bay are lacking in some environmental and macrobenthic data. However, they are thought to be normal stage because there was no sign of eutrophication in water and bottom environments, and in the surveys in November, 1975 and June, 1976 the number of species and species diversity were both fairly high (number of species 13–27 per m^2, species diversity H' 3.17–4.20).

IV-3 Some biological data of the four types of *Paraprionospio*

Relation between body width and some other factors

Log body width is directly related to log wet weight as shown in Fig. 16 and body width is also directly related to total length as shown in Fig. 17. Setigers tend to approach constant number gradually with increasing body width (Fig. 18). Therefore, the total weight, total length and number of setigers can be estimated from the body

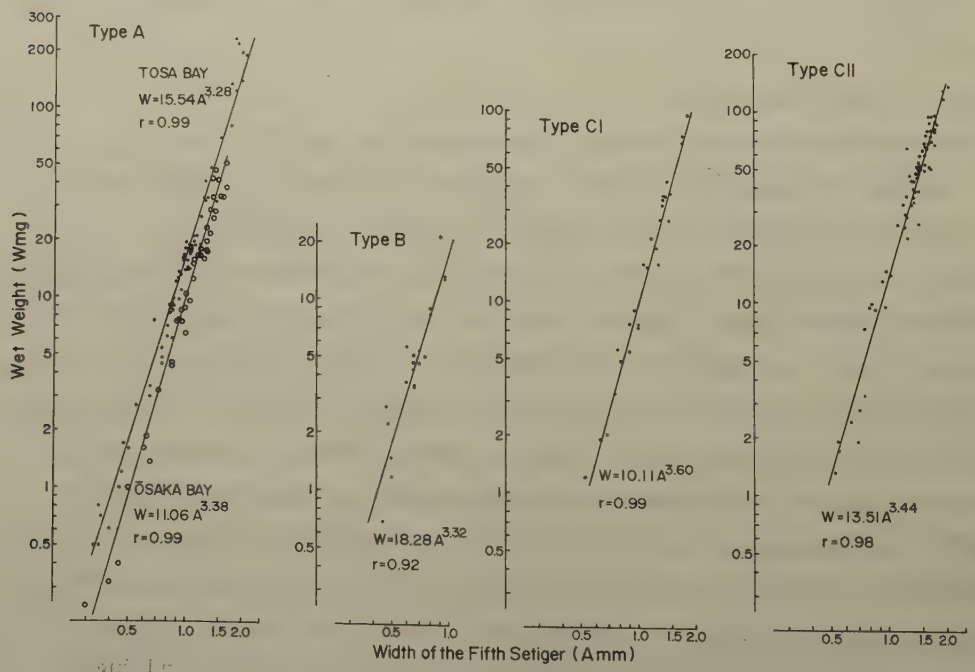


Fig. 16 Log width-log wet weight relationship of *Paraprionospio*. r shows correlation coefficient.

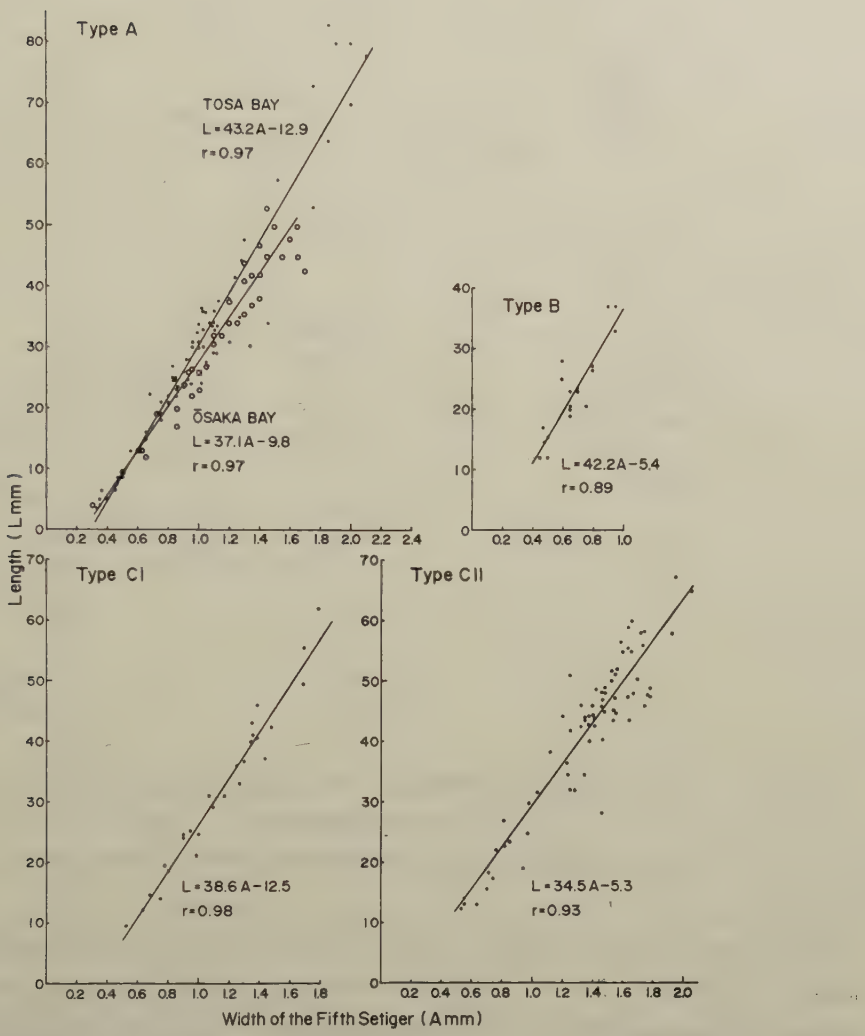


Fig. 17 Width-length rlelationship of *Paraprionospio*. r shows correlation coefficient.

width, even if the worm is damaged.

Eggs and sperm

The eggs of all four types fixed in formalin solution are light orange in color and nearly spherical in shape but sometimes distorted or flat. Type CII has the largest egg diameter of all four types. Mature egg diameter of type CII is 120-220μm, and that of the other three types is about 100-170μm. Number of the eggs per female is directly related to body weight (Fig. 19). Egg number per female of type A is about twice as many as that of types CI and CII in the case of the same body weight. For example, a type A female of 100mg in body weight produces about 41,000 eggs and the type CI and CII of the same weight produce about 21,000 eggs. Maximum egg number of type A measured is more than 100,000, and that of type CI and CII is about 26,000-

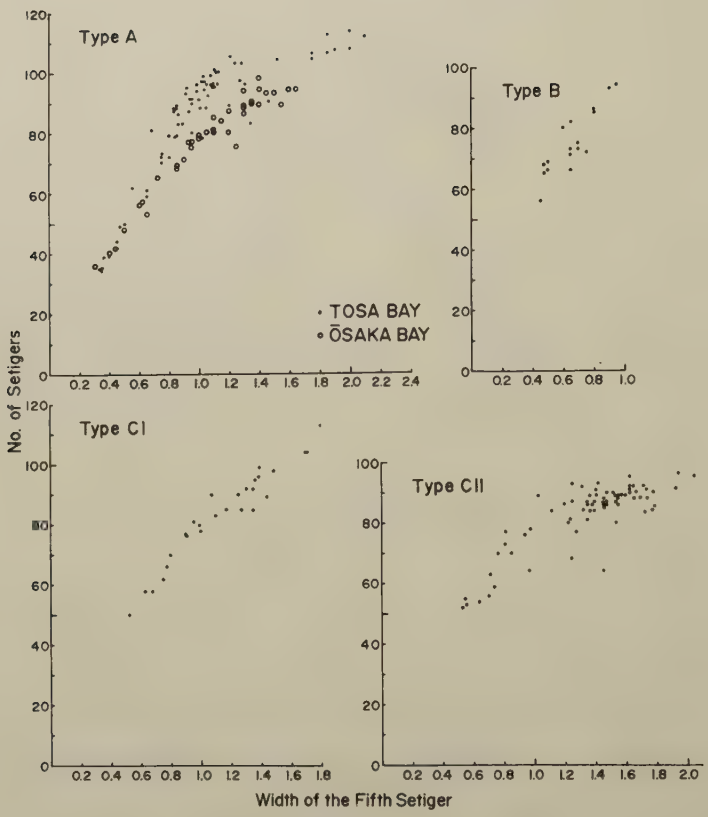


Fig. 18 Width-number of setigers relationship of *Paraprionospio*.

28,000. The exact egg number of type B is unknown because no complete females with eggs were obtained. But the maximum number is roughly estimated about 10,000 from the egg diameter and the maximum body weight. Type A has a pelagic larval stage (YOKOYAMA, 1981), and judging from the egg diameter and the egg number produced by a female (THORSON, 1950; HERMANS, 1979), types B, CI, CII are also probably thought to undergo pelagic development.

The sperm morphology of the four types resembles each other very well. It is difficult to distinguish them under the light microscope. Fig. 20, for instance, shows the sperm morphology of type A. The sperm is composed of a nearly spherical head, a small middle piece and a long tail.

Eggs and sperm of all four types are observed first from setiger 14–21 and are observed to the almost rear end. The male and female resemble each other very well in external morphology. So, adult worms which have lost their setigers containing eggs or sperm, or young worms not containing eggs or sperm can not be sexed.

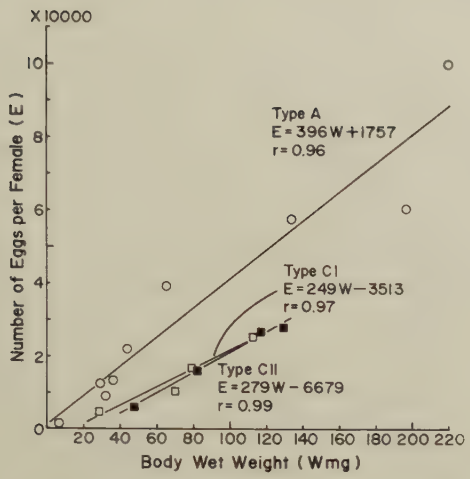


Fig. 19 Body wet weight-number of eggs per female relationship of *Paraprionospio*. r shows correlation coefficient.

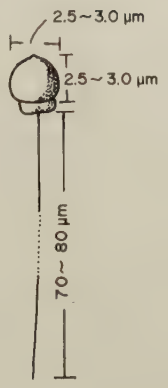


Fig. 20 Sperm of *Paraprionospio* sp. (type A).

IV-4 Life history

Type A

Osaka Bay: As mentioned in chapter III, type A was distributed at the depths shallower than 20m in Osaka Bay. In 1979-1980 surveys, a large number of type A were collected at Stns. 1 and 2 shallower than 15m in depth, whereas hardly collected at Stns. 3-5 deeper than 20m in depth (Fig. 21). Annual mean density of this type at Stn. 1 (10m in depth) reached 1641 individuals per m^2, and at Stn. 2 (15m in depth) showed 174 individuals per m^2.

The seasonal changes in density of type A at Stn. 1 was entirely different from that Stn. 2 (Fig. 22). At Stn. 1, the density was fairly stable at the level of about 250 individuals per m^2 from April to early July, then increased rapidly from late July to August, and reached about 6000 individuals per m^2 from September to October. Such a rapid increase in density was due to the recruitment of very many juveniles. Rapid decrease took place after November. The density from December to March fell to about 50 individuals per m^2. At Stn. 2, the density of type A exceeded 1000 individuals per m^2 in

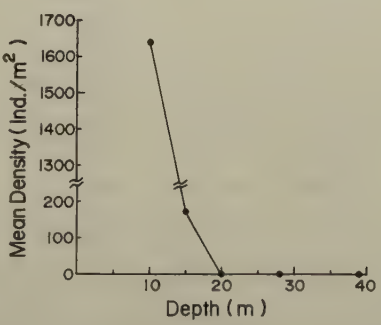


Fig. 21 Relation between water depth and annual mean density of *Paraprionospio* sp. (type A) in Osaka Bay from April 18, 1979 to March 9, 1980.

spring, but diminished from June to July, and this type was absent or extremely rare after August. Seasonal changes in the percentage composition of type A in density at each station were similar well to that in the density (Fig. 23).

Fig. 24 shows body width-frequency histograms at Stn. 1. It is easy to follow peaks through from month to month. Recruitment of benthic juveniles occurred from late July to early September. Some of these juveniles were about 4mm in total length and had about 40 setigers, which are thought to be the specimens immediately after the settlement (YOKOYAMA, 1981). The growth took place rapidly from September to October. The maximum growth rate was estimated at 11.4mg and 19.8mm per month from the mean body width on September 2 and September 16, 1979. The growth was slow in cold months. It began again from April. Specimens with eggs or sperm were observed from middle of May to early September. Judging from the seasonal change in egg diameter (Fig. 25A) and the appearance of the specimens with gametes, spawning season is considered to begin in mid-June and to continue for about two months. Pelagic stage of the larva is considered to be about a month because the settlement occurred about a month after the beginning of spawning. The longevity is about a year. Some part of the juveniles already contained large eggs more than 100μm in diameter or ripe sperm from August to September (Figs. 24, 25B),

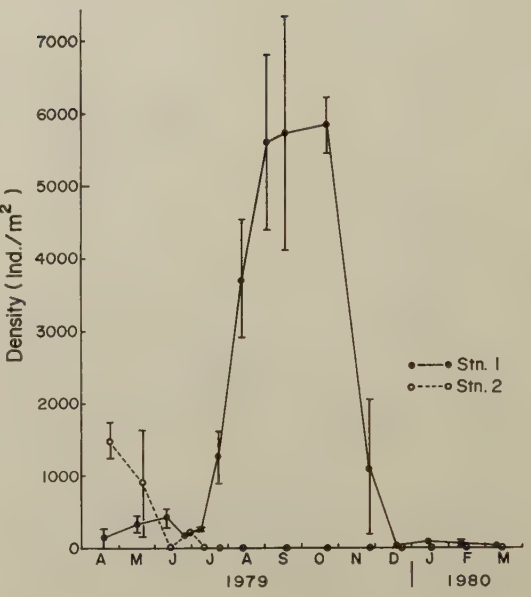


Fig. 22 Seasonal changes in density of *Paraprionospio* sp. (type A) in Osaka Bay from April 18, 1979 to March 9, 1980. Closed and open circles show mean value and vertical bar shows standard deviation.

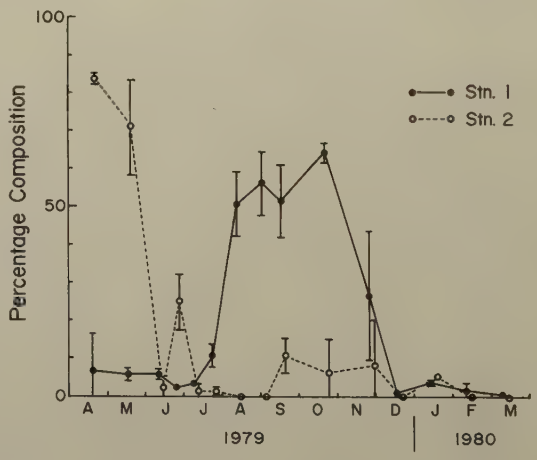


Fig. 23 Seasonal changes in percentage composition of *Paraprionospio* sp. (type A) in density in Osaka Bay from April 18, 1979 to March 9, 1980. Closed and open circles show mean value and vertical bar shows standard devitation.

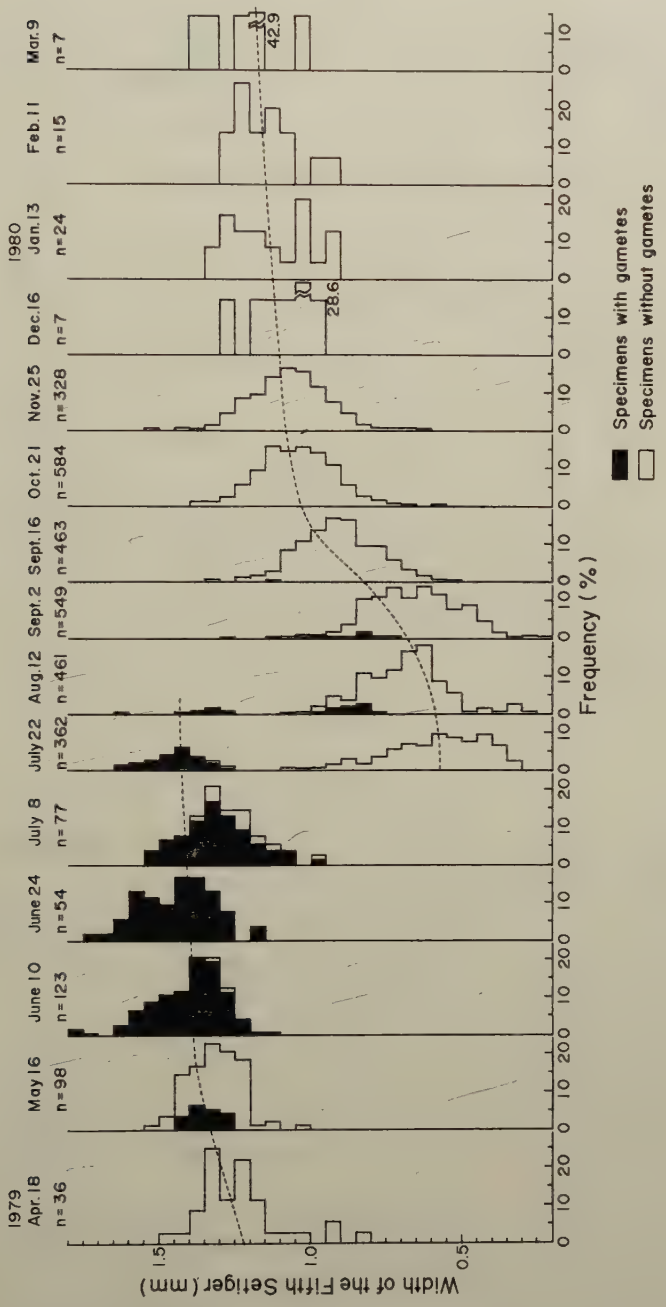


Fig. 24 Seasonal changes in body width frequency of *Paraprionospio* sp. (type A) at Stn. 1 in Osaka Bay from April 18, 1979 to March 9, 1980. n shows the number of measured specimens. A dotted line was drawn from mean body width of each size group.

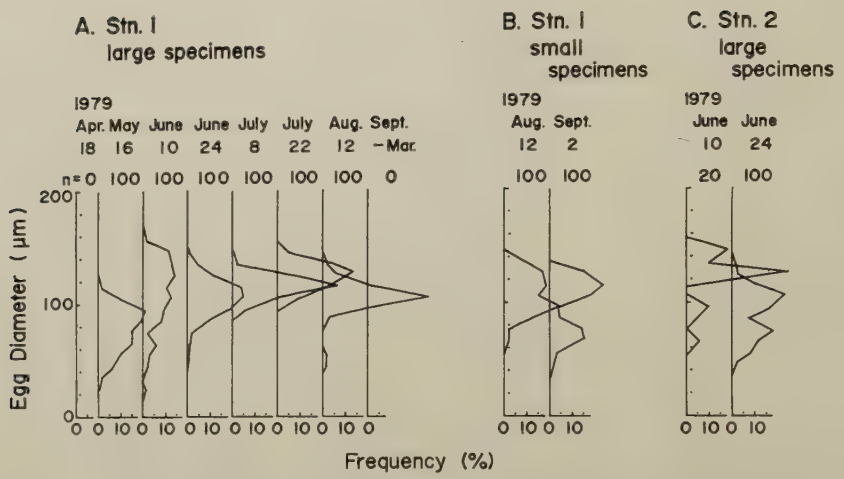


Fig. 25 Seasonal changes in egg diameter of *Paraprionospio* sp. (type A) at Stns. 1 and 2 in Osaka Bay. Large specimens are larger than 1mm in body width and small specimens are smaller than 1mm in body width. n shows the number of measured eggs.

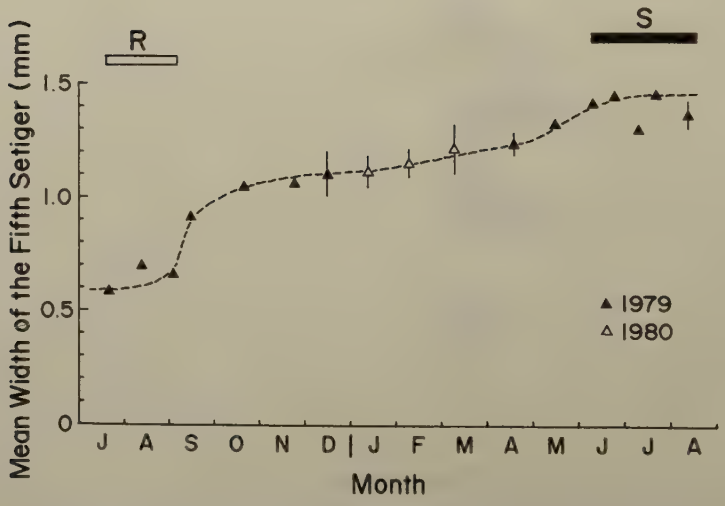


Fig. 26 Growth curve of *Paraprionospio* sp. (type A) at Stn. 1 in Osaka Bay. Vertical bar shows 95% confidence limits. R: recruitment period. S: spawning period.

which displays the ability of the rapid sexual maturity of type A. However, the new recruitment due to the spawning of these small precocious worms was not observed, probably because the density of such worms was low and they have only a small number of eggs per female. The smallest specimen containing gametes was 0.75mm in width, 20mm in length and 6mg in weight. These results are summarized in Fig. 26.

At Stn. 2, the growth from spring to summer was very ill and the percentage of the specimens with gametes was low (Fig. 27). But since large eggs more than 100μm in diameter were observed (Fig. 25C), the spawning seems to occur.

It is clear from the described facts that Stn. 1 is the suitable habitat for type A, where this type can maintain the stable life cycle. At Stn. 2, the recruitment of type A in 1978 was successful, which is deduced from high population density in the spring of 1979, however, the recruitment in 1979 was very poor. This shows that Stn. 2 is not always the suitable habitat for type A.

Tosa Bay: In Tosa Bay, type A was abundant at the depth of 15m (Stn. L) and the mean density in 1977–1981 was 82.4 individuals per m^2 (Table 4). The seasonal change in the density of type A at Stn. L was not necessarily similar from year to year, but relatively high density (200–500 individuals per m^2) was usually observed in summer months. The percentage composition indistinctly showed somewhat high value (15–30%) from June to December.

Fig. 28 shows the growth curve. There are two recruitment periods, one is the early summer months (May to July) and the other is the fall months (October to November). The major recruitment period is probably the former. The life history of early summer recruitment group is similar to that at Stn. 1 in Osaka Bay. The growth was fast from July to October. It almost stopped in winter and began again in spring. The spawning season was from April to July. In this period, the females have the many large eggs more than 100μm in diameter. The longevity is about a year. The fall recruitment juveniles are derived from the spawning of some precocious individuals settled in early summer months. They grew rapidly and this recruitment group and early summer recruitment group united to form one group in spring.

According to some ecological observations, this type lives in the fragile tube made of a mucoid secretion, and stretches the palpi, branchiae and anterior end of the body out of the tube for feeding and respiration. Type A seems to feed on the suspended and deposited organic particles.

The life history in Tosa Bay is different from that in Osaka Bay to some extent, however, the breeding is roughly restricted to warm season in both areas.

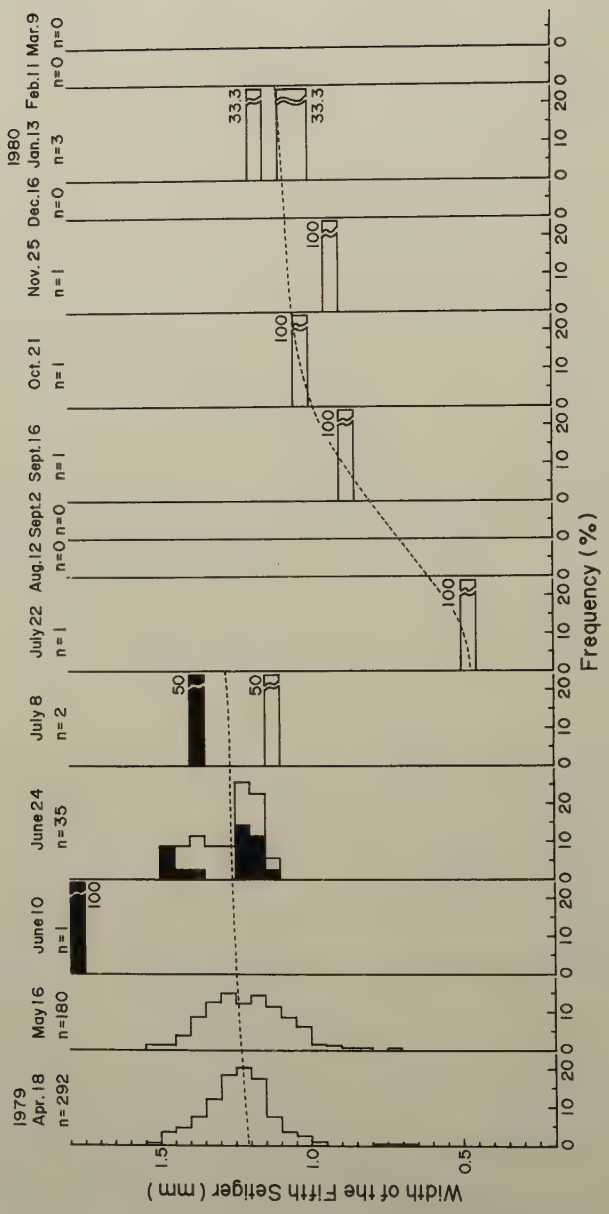


Fig. 27 Seasonal changes in body width frequency of *Paraprionospio* sp. (type A) at Stn. 2 in Osaka Bay from April 18, 1979 to March 9, 1980. See Fig. 24.

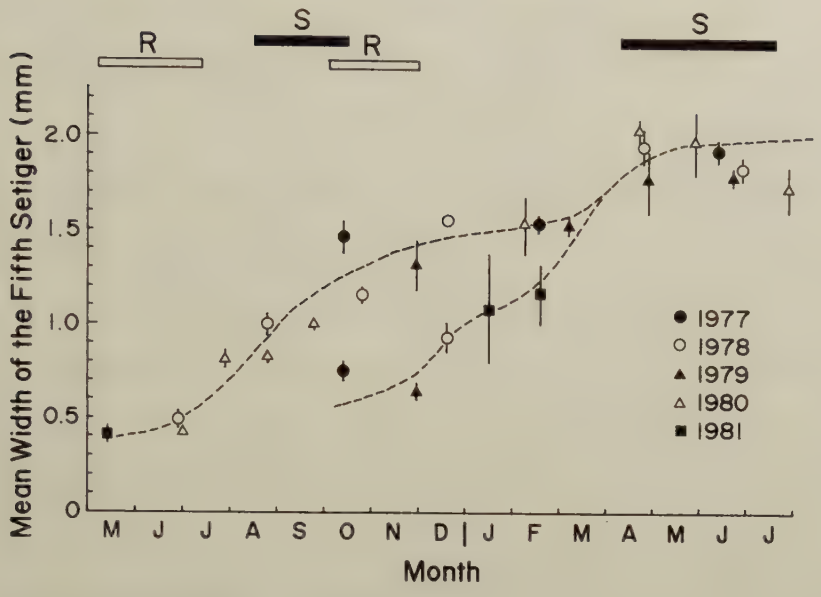


Fig. 28 Growth curve of *Paraprionospio* sp. (type A) at Stn. L in Tosa Bay. See Fig. 26.

Type B

Type B was collected in Hiuchi-nada and at Stns. 2-5 in Osaka Bay. In Hiuchi-nada, mean density per m^2 was 10.9 (shallower than 15m in depth) and 23.9 (deeper than 15m in depth), mean percentage composition was 1.1 (shallower region) and 9.0 (deeper region). In Osaka Bay, mean density per m^2 was 0 (Stn. 1), 12.7 (Stn. 2), 12.3 (Stn. 3), 4.0 (Stn. 4) and 7.7 (Stn. 5), and mean percentage composition was 0 (Stn. 1), 6.6

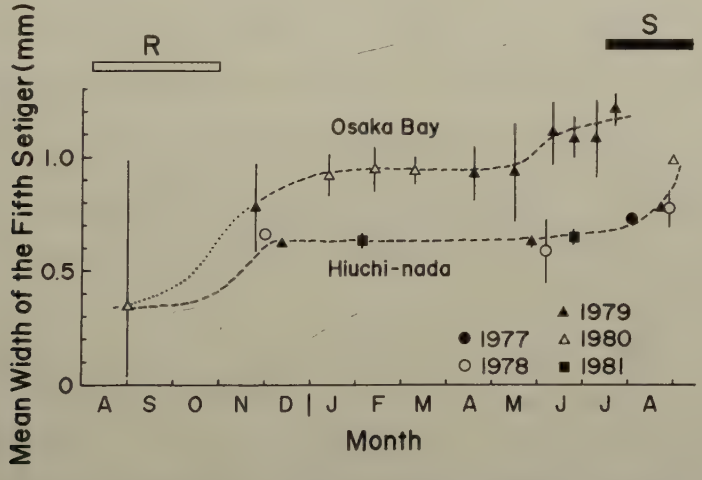


Fig. 29 Growth curve of *Paraprionospio* sp. (type B) at Stns. 2 and 3 in Osaka Bay and the area deeper than 15m in depth in Hiuchi-nada. See Fig. 26.

(Stn. 2), 11.7 (Stn. 3), 2.2 (Stn. 4) and 2.1 (Stn. 5). The life history of type B was examined at the bottom deeper than 15m in Hiuchi-nada and Stns. 2 and 3 in Osaka Bay, where the density and the percentage composition were both relatively high. These stations are probably the suitable habitat of type B.

Fig. 29 shows the growth curve. The recruitment seems to take place from late summer to fall. But, only small number of the juveniles was collected during this period, probably because of the use of 1mm mesh sieve for collection except the case of Hiuchi-nada after December, 1979. 1mm mesh is too large for collecting the juvenile individuals effectively. Growth occurred from fall to January and in summer. It stopped from February to spring. In summer body width reached 0.8mm in Hiuchi-nada and 1.1mm in Osaka Bay. The individuals with gametes were collected in summer, namely, only in August in Hiuchi-nada and from early June to early September in Osaka Bay. Mean egg diameter was smaller than 100μm till early July and then exceeded 100μm for about two months. So, it is supposed that the spawning took place from July to September. The longevity is about a year.

Type CI

The distribution depth range of type CI in Tosa Bay was 15–110m. Mean density and mean percentage composition in this area from 1977 to 1981 were both extremely low, 2.1 individuals per m^2 and below 1% respectively. The density, percentage composition and body width did not show the apparent seasonal fluctuation at all. For these reasons, the life history of type CI could not be clarified.

Type CII

Type CII inhabited at the depths 25–98m in Tosa Bay and was collected frequently on muddy sand bottom deeper than 35m, so the specimens collected at the stations of 35–70m water depth and Stn. N (80m in depth) were used for the life history study of this type.

Fig. 30 shows the growth curve. The benthic juveniles were recruited from October to winter and grew from winter to spring. They seem to be matured and spawn from June to October, when the eggs were fairly large, 130–180μm in mean diameter. The longevity is about a year.

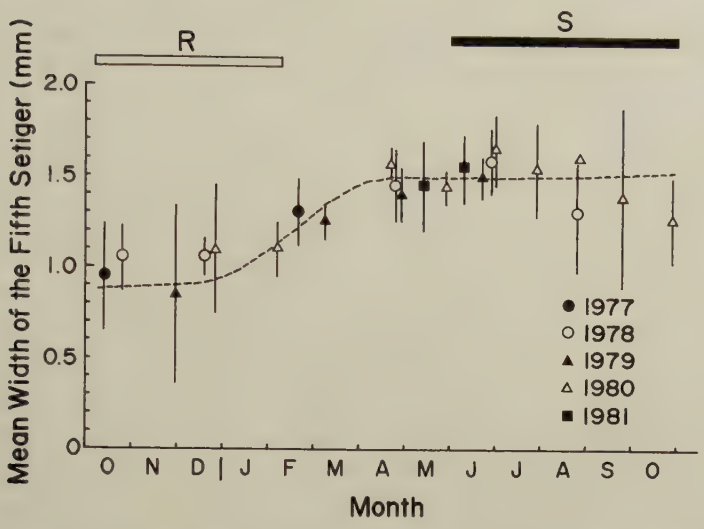


Fig. 30 Growth curve of *Paraprionospio* sp. (type CII) at a depth of 35–80m in Tosa Bay. See Fig. 26.

V Four types of *Paraprionospio* as environmental indicators

Single species or species group is frequently used to indicate some environmental conditions (KITAMORI, 1963; BAGGE, 1969; PEARSON, 1971, 1975; LEPPÄKOSKI, 1975; ROSENBERG, 1976 etc.). For example, *Capitella capitata*, *Scolelepis fuliginosa*, *Streblospio benedicti*, *Polydora ligni*, *P. ciliata*, *Hydrobia ulvae* and so on are known to be species associated with organic pollution (PEARSON and ROSENBERG, 1978). The reasons why some indicator species can live and flourish under some environmental conditions are also important subjects to be investigated. In this chapter, utility of the four types of *Paraprionospio* as environmental indicators and the reasons for their prosperity will be discussed. For this purpose, the biological and ecological knowledge of the objective species and the information about the macrobenthic community and environmental conditions are needed. They were given in chapter III-IV.

Type A

As shown in chapter III, type A is a coastal waters species to live mainly shallower than 20m in depth. Coastal waters frequently undergo organic pollution by the organic-rich fresh water inflow. If there is some relation between eutrophic stage and type A, we can use this type as its indicator. Therefore, the relations between eutrophic stages and the three factors of type A (density, percentage composition in density, rank in density) were examined (Table 14). These factors were somewhat high at Stn. L in Tosa Bay (normal zone), and very high at Stn. 1 in Osaka Bay (hypertrophic zone)

Table 14 Relation between *Paraprionospio* sp. (type A) and eutrophic stage. Each value was calculated from all surveys dealt in chapter IV. Only rank in Tosa Bay was determined from the surveys from April 22, 1980 to July 8, 1981.

Eutrophic Stage	Area	Station	Depth (m)	Type A				
				Ind./m²		Percentage composition		Rank in density
				Mean	(Range)	Mean	(Range)	
Normal	Tosa Bay	L	15	82.4	(0–473)	6.8	(0–28.0)	11
		M	25	0.3	(0–2)	0.1	(0–0.3)	20<
		N	80	0	(0–0)	0	(0–0)	
	Osaka Bay	4	28	0	(0–0)	0	(0–0)	
		5	39	0	(0–0)	0	(0–0)	
Hypertrophic	Osaka Bay	1	10	1641.3	(23–5807)	19.4	(1.0–64.2)	1
	Hiuchi-nada		15>	0	(0–0)	0	(0–0)	
Polluted	Osaka Bay	2	15	173.7	(0–1475)	14.4	(0–83.7)	1
		3	20	0.3	(0–5)	0.2	(0–2.6)	20<
	Hiuchi-nada		15≦	0	(0–0)	0	(0–0)	

and Stn. 2 in Osaka Bay (polluted zone). Especially at hypertrophic and polluted zones, type A was the most dominant species and sometimes reached very high density (1500–6000 individuals per m^2) and very high percentage composition (65–85%). Also at Stn. L in Tosa Bay, type A sometimes showed 200–500 individuals per m^2 in density, and 15–30% in percentage composition. But these values are fairly low as compared with those at Stns. 1, 2 in Osaka Bay, and the rank in density is the eleventh. Type A in Tosa Bay is merely one of the constituents of the community (Figs. 15, 31c). After all, it is concluded that the dominant and numerous appearance of type A suggests eutrophication. However, type A is not always dominant even at hypertrophic or polluted zone as observed in Hiuchi-nada and at Stn. 3 in Osaka Bay.

Why can type A sometimes prosper very well at hypertrophic or polluted zone? In the case of the hypertrophic zone, namely, Stn. 1 in Osaka Bay, the reason is probably that the ecological and physiological features of type A are suitable to live in eutrophic areas. Type A is characterized by the summer recruitment, rapid growth and fairly high tolerance to physico-chemical environmental factors such as low oxygen concentration, low oxidation-reduction potentials, high H_2S. The settlement period of type A (late July-early September) coincided with the rapid decrease period in the density of the other benthic animals (Fig. 31A). Surplus habitat and food are probably produced by this decrease, and just then the juveniles of type A are settled, use these sufficient surplus and grow rapidly. It seems probable that the decrease in density of the benthic animals except type A is due to the loss of the species which can not tolerate low oxygen concentration, because the decrease in density occurred with the

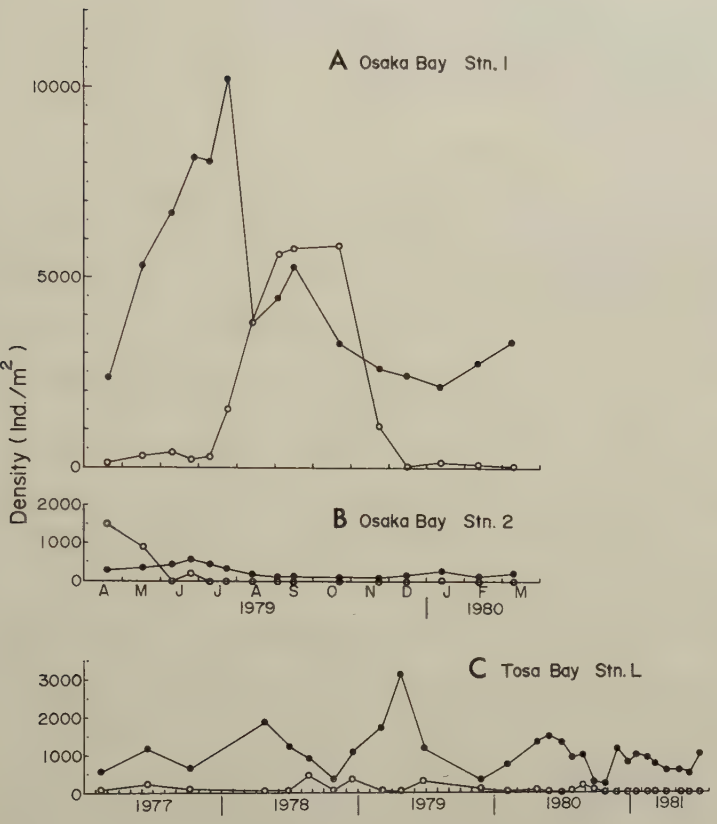


Fig. 31 Seasonal changes in density of *Paraprionospio* sp. (type A) (○) and density of total benthic animals except type A (●) in Osaka Bay and Tosa Bay.

summer oxygen deficiency of bottom water. Polychaetes *Euchone* sp., *Pseudopolydora* sp., crustacean *Corophium acherusicum*, echinoderm *Ophiophragmus japonicus*, molluscs *Musculus senhausia*, *Raete rostralis*, *Theora lubrica* decreased rapidly in this period (Fig. 11, Appendix table 1). However, type A can be recruited and survive under low oxygen conditions. Probably for above mentioned reasons, type A can prosper in hypertrophic zone. That is to say, the prosperity of type A is thought to be caused by eutrophication. This supports that the use of type A as an eutrophic indicator is reasonable.

The prosperity of type A at Stn. 2 in Osaka Bay (polluted zone) seems to be mainly dependent on the tolerable ability of type A to the physico-chemical environment. At this station, the period when type A settles is not so important because the sediment in this station has a large amount of organic matter which is used for food and because density of the benthic animals except type A is fairly low throughout the year (Fig 31B). Therefore, whenever type A settles, this type will find sufficient food and habitat.

Type A is mainly distributed in coastal waters shallower than 20m in depth, and the

areas where the density, percentage composition and rank in density of type A are high are hypertrophic or polluted zone. Thus, type A can be utilized for the eutrophic indicator on coastal waters.

Type B

Type B is an inland sea mud and muddy sand bottom species. A little deeper mud bottom in inland sea is thought to be an area where the organic matter is resedimented. Type B is mainly distributed in such areas. Therefore, there is a possibility that this type can be also used as an eutrophic indicator like type A. The relations between eutrophic stages and the three factors of type B (density, percentage composition in density, rank in density) were shown in Table 15. Since type B lives in every zone,

Table 15 Relation between *Paraprionospio* sp. (type B) and eutrophic stage. Each value was calculated from all surveys dealt in chapter IV.

Eutrophic stage	Area	Station	Depth (m)	Type B				
				Ind./m² Mean	(Range)	Percentage composition Mean	(Range)	Rank in density
Normal	Tosa Bay	L	15	0	(0–0)	0	(0–0)	
		M	25	0	(0–0)	0	(0–0)	
		N	80	0	(0–0)	0	(0–0)	
	Osaka Bay	4	28	4.0	(0–15)	2.2	(0–8.3)	16
		5	39	7.7	(0–50)	2.1	(0–7.7)	9
Hypertrophic	Osaka Bay	1	10	0	(0–0)	0	(0–0)	
	Hiuchi-nada		15>	10.9	(0–43.3)	1.1	(0–4.0)	20<
Polluted	Osaka Bay	2	15	12.7	(0–60)	6.6	(0–20.0)	6
		3	20	12.3	(0–50)	11.7	(0–30.0)	1
	Hiuchi-nada		15≦	23.9	(0.6–83.6)	9.0	(0.3–37.2)	2

the presence of this type itself does not serve as an indicator of eutrophication. But the density, percentage composition and rank are all higher in polluted zone than in normal and hypertrophic zone. Thus, the eutrophic stage may be estimated by these values. The percentage composition shows eutrophic stage more distinctly than the density, because in polluted zone the increase in density of type B and the decrease in total density of benthic animals usually occurs simultaneously, and consequently the relative rate of type B becomes high. The percentage composition is more suitable for eutrophic indicator than the density.

Type B mainly inhabits the area where the organic matter in sediment is rich and the density of benthic animals is low or moderate throughout the year. This type seems to feed on deposited or near bottom suspended particles (TAGHON et al., 1980; DAUER et al., 1981). Consequently, whenever type B settles, this type will be able to

find the foods and habitat sufficiently. Therefore, the period when this type is recruited is not so important. The prosperity of type B may be dependent on the fairly high tolerance to physico-chemical enviromental factors peculiar to eutrophic areas, such as low oxygen concentration, low oxidation-reduction potentials, high H_2S concentration. However, it is not clear why the density of type B does not become so high.

The density, percentage composition and rank of types A and B can be used for the eutrophic indicators. Type A prospers especially in coastal hypertrophic zone and type B prospers in a little deeper polluted zone. By using both types together, we will be able to estimate eutrophic areas more distinctly.

Type CI

Type CI was collected in a wide variety of habitats and the density is usually very low. The life history can not be clarified. For these reasons, the use of this type for an indicator organism is difficult.

Type CII

Type CII is an offshore waters species. It was collected on muddy sand bottom deeper than 35m in Tosa Bay and was not recorded in an inland sea region at all. Oceanographic conditions in offshore region are characterized by the small variation of water temperature and high and stable salinity. At the depth of 80m in Tosa Bay, which is the suitable habitat for type CII, the difference between minimum and maximum temperature was 6.1°C and salinity ranged from 34.54 to 34.88‰. Type CII will be restricted to some extent by these oceanographic conditions.

Type CII will be able to be utilized for an offshore waters indicator organism and we can estimate the area influenced by offshore water using this type.

VI Discussion

The genus *Paraprionospio* now consists of the four species, *P. pinnata* (EHLERS, 1901), *P. africana* (AUGENER, 1918), *P. treadwelli* (HARTMAN, 1951) and *P. lamellibranchia* HARTMAN 1974 (YOKOYAMA and TAMAI, 1981). *P. pinnata* is a cosmopolitan species (FOSTER, 1969, 1971; BLAKE and KUDENOV, 1978; LIGHT, 1978). *P. africana* was reported from off western Africa (AUGENER, 1918; MONRO, 1930). *P. treadwelli* was recorded from off eastern U. S. A. (HARTMAN, 1951) and *P. lamellibranchia* was recorded from the Mozambique Channel and the northern Indian Ocean (HARTMAN, 1974). The original morphological descriptions of these four species are, however, all insufficient and the characters used for discrimination among the present four types (A, B, CI and CII) are not almost treated in previous studies (YOKOYAMA and TAMAI, 1981). Furthermore, even the de-

scription of *P. pinnata*, the most common *Paraprionospio* species, is taxonomically confused. For example, FOSTER (1969) stated that *P. pinnata* had or did not have the filament at the base of the third branchia, transverse dorsal crests and transparent dorsal cuticle. However, these must be the important characters to divide into species or subspecies. There is also the disagreement in the shape of branchial lamellae (YOKOYAMA and TAMAI, 1981). As shown in this paper, the present four types are distinguished not only by morphological characters but also by ecological items, such as habitat preference, maximum density attainable, adult size and number of the eggs per female. These facts suggest that each type can be treated as valid species. But, because of the insufficiency of the previous descriptions, the examinations of both the type specimens of each species and the specimens collected all over the world are needed for the identification of the present four types. For this reason, the species name could not be determined in this study.

According to this study and TAMAI (1981), YOKOYAMA and TAMAI (1981), the geographical distribution of each type of *Paraprionospio* in Japan is as follows: Type A occurs on the Pacific side from off Ibaragi prefecture southward to Tosa Bay, in Seto Inland Sea and on the Japan Sea side from Wakasa Bay to off Tottori prefecture. Type B occurs in Kii Channel, Seto Inland Sea, Wakasa Bay and Ariake Sea. Type CI occurs on the Pacific side from off Ibaragi prefecture southward to Kyushu, in Seto Inland Sea and Wakasa Bay. Type CII occurs in Tanabe Bay, Tosa Bay and Wakasa Bay. "*P. pinnata*" was also collected in further northern areas exceptionally, namely, Hakodate Bay in Hokkaido (NAKAO, 1982) and Nanao Bay in Ishikawa prefecture (MIYADI and MASUI, 1942b). But the distributional area of *Paraprionospio* in Japan is almost restricted northward to 37°N, which is approximate northern limit of the effects of the warm Kuroshio and Tsushima Currents.

There are two methods in order to estimate environmental conditions from benthic animals. One is the method using the characteristics which express the community structure and the other is the method using indicator organisms. KITAMORI (1975) and PEARSON and ROSENBERG (1976, 1978) have mentioned that the structural change in quantitatively sampled benthic communities is more useful and the indicator organisms only play a supplemental role. Certainly, the characteristics of community structure shown by biomass, density, number of the species, diversity and similarity are all good indicators. But, to calculate number of the species, diversity and similarity of benthic communities, we must identify all collected specimens. For this purpose, wide taxonomic knowledge and time-consuming procedure are needed. On the contrary, the indicator organisms associated with some environment enable us to recognize the environmental

conditions intuitively and quickly, though the accuracy may not be so good. For example, as shown in this study, we can recognize degree of eutrophication of the region by use of types A and B. The appearance of type CII shows the influence of offshore water.

Both type A and type B are good indicator of eutrophic zone, but they are also sometimes collected in normal zone. Then recognition of eutrophic zone can be done by their density, percentage composition and dominance rank in density. Identification of these types is easy. In the case of type CII, the distribution is completely restricted to offshore waters and this type appears there frequently. The identification is not so difficult. These three types are practically useful as indicator organisms.

Generally, the utility as an indicator organism changes seasonally because the density usually shows seasonal fluctuation. The survey should be carried out in the period when the many specimens of indicator organisms can be collected, namely, the recruitment period and the little later. The suitable season for the survey is from summer to fall for type A and is from fall to winter for type B.

In inland sea region, polluted area and the degree of pollution could be roughly estimated also by the previous method using "*P. pinnata*" (KITAMORI, 1969; JOH et al., 1969, 1978a; SANUKIDA et al., 1979, 1981) because, in this region, "*P. pinnata*" is mainly composed of type A and type B, both of which are useful eutrophic indicator organisms. Type CI is also sometimes distributed in this region, but usually the density is very low, therefore, the distributional pattern of "*P. pinnata*" is scarcely influenced by the presence of this type. In offshore region, "*P. pinnata*" is composed of types A, CI and CII. Especially, deeper than 25m in depth, only types CI and CII are mainly distributed. These two types are independent of eutrophication and pollution.

In Japan, semelid small bivalve *Theora lubrica* is also used as an eutrophic indicator (KIKUCHI and TANAKA, 1976; SANUKIDA et al., 1979, 1981; IMABAYASHI, 1983). This species is widely distributed in the area of strong embayment degree (MIYADI et al., 1944b; HABE, 1956), and the density sometimes exceeds 1000 individuals per m^2 (KIKUCHI and TANAKA, 1976, 1978). The mode of seasonal change in population and settlement period of benthic juveniles considerably vary with locality (MUKAI, 1974; KIKUCHI and TANAKA, 1976; SANUKIDA et al., 1979, 1981). The species has short life span, rapid growth and small maturation size (KIKUCHI and TANAKA, 1976). The data in the present study show that *T. lubrica* and type B have similar distributional area. Both species were widely distributed on mud and muddy sand bottom in inland sea area. However type B tends to be abundant in mud bottom area where the oxygen deficiency happens rather strongly (e. g. Stns. 2 and 3 in Osaka Bay, deeper than 15m in Hiuchi-

nada), while *T. lubrica* is usually abundant in the area where oxygen deficiency does not happen so strongly (e. g. Stns. 4 and 5 in Osaka Bay, shallower than 15m in Hiuchi-nada). KIKUCHI (1964) said that in brackish lagoon, Nakaumi, all benthos including bivalve molluscs *T. lubrica* and *Raeta pulchella* died out but only "*P. pinnata*" remained alive under severe dissolved oxygen deficiency in summer. SANUKIDA et al. (1984) also reported in eastern Hiuchi-nada that when dissolved oxygen fell below 2.0ppm in September, *T. lubrica* died completely but type B could survive.

Comparing the life history of type A in Osaka Bay with that in Tosa Bay, it is noticed that the reproductive period begins earlier and is longer in Tosa Bay. There are many factors affecting reproduction (SCHROEDER and HERMANS, 1975), but generally temperature is thought to be the most important one. At first, this difference of life history between these two areas was seemed to be due to the difference of water temperature. The reproductive period of type A is restricted roughly in warm season. In Tosa Bay, the minimum temperature is about 7°C higher than in Osaka Bay and duration higher than 20°C is about 50 days longer. As a result, the reproductive period will become earlier and longer in Tosa Bay. However, in Kumihama Bay, which is colder than Osaka Bay, pelagic larvae were mainly collected during the fairly long period of May to December, recruitment occurred from July to December and the specimens with gametes were observed throughout the year (YOKOYAMA, 1982). The life history of type A in Kumihama Bay is rather similar to that of Tosa Bay than Osaka Bay. This fact shows that the temperature is not the only factor affecting gametogenesis and spawning of this type. But at least it is certain that the annual life cycle is repeating regularly every year and that the settlement period is restricted to summer and fall seasons in all these three areas.

In order to inhabit polluted area, the organisms must undoubtedly have tolerable ability to physico-chemical environmental conditions peculiar to polluted area, such as low oxygen concentration and high H_2S concentration. Besides this ability, the opportunistic nature of pollution indicator species has also recently been brought under workers' notice (GRASSLE and GRASSLE, 1974; WARREN, 1976, 1977; KIKUCHI and TANAKA, 1976). Among several characteristics with opportunistic species, it is thought to be especially important that reproduction occurs asynchronously, and consequently the breeding season of population is extremely extensive, because the rapid colonization into unpredictably produced vacant habitat is largely due to this characteristics of life history. Some species which are numerically abundant in polluted area have this nature. For example, capitellid polychaete *Capitella capitata* (GRASSLE and GRASSLE, 1974; WARREN, 1976; TSUTSUMI and KIKUCHI, 1984) and semelid mollusc *Theora lubrica* (KIKUCHI

and TANAKA, 1976) are known as an opportunistic species. *Paraprionospio* sp. (type A) also sometimes shows extremely high density in eutrophic area, however, this type reveals not opportunistic, but fairly fixed life history. Type A can flourish eutrophic environment probably because this type has the high tolerable ability to low oxygen concentration and because the settlement occurs in the period advantageous to this type. In the present study, an experiment on the tolerance to low oxygen concentration in type A could not be made. There are, however, some supporting evidences for high tolerable ability of type A to low oxygen concentration. In Kumihama Bay, a large number of the pelagic larvae of type A were found in the water mass where the content of dissolved oxygen was less than 10% in saturation (YOKOYAMA, 1982). In Osaka Bay, many individuals of type A settled during the period of oxygen deficiency in summer. It is also important for the prosperity of type A that the settlement period of this type coincides with the declining period of many other species. This coincidence is of advantage to type A as regards the assurance of food and habitat for this type. Type A has a good adaptation to eutrophic environments in regard to both physiological tolerance and the timing of the settlement.

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References

AUGENER, H., 1918: Polychaeta. Beitrage zur Kenntnis der Meeresfauna West-Afrikas, **2**, 67–625.

BAGGE, P., 1969: Effects of pollution on estuarine ecosystems. I. Effects of effluents from wood-processing industries on the hydrography, bottom and fauna of Saltkallefjord (W. Sweden). Merentutkimuslait. Julk., Skr. **228**, 3–118.

BLAKE, J. A. and J. D. KUDENOV, 1978: The Spionidae (polychaeta) from southeastern Australia aud adjacent areas with a revision of the genera. Mem. Nat. Mus. Vic., **39**, 171–280.

BOESCH, D. F., 1973: Classification and community structure of macrobenthos in the Hampton

Roads. Mar. Biol., **21**, 226–244.

Caullery, M., 1914: Sur les polychetes du genre *Prionospio* Mgn., Bull. Soc. Zool. Paris, **39**, 355–361.

Dauer, D. M. and W. G. Conner, 1980: Effects of moderate sewage input on benthic polychaete populations. Estuar. Mar. Sci., **10**, 335–346.

Dauer, D. M., C. A. Maybury and R. M. Ewing, 1981: Feeding behavior and general ecology of several spionid polychaetes from the Chesapeake Bay. J. exp. mar. Biol. Ecol., **54**, 21–38.

Ehlers, E., 1901: Die Polychaeten des magellanischen und chilenischen Strandes. Festschr. K. Ges. Wiss. Göttingen (Math. Phys.), 232pp.

Foster, N. M., 1969: New species of spionids (polychaeta) from the Gulf of Mexico and Caribbean Sea with a partial revision of the genus *Prionospio*. Proc. Biol. Soc. Wash., **82**, 381–400.

Foster, N. M., 1971: Spionidae (polychaeta) of the Gulf of Mexico and the Caribbean Sea. Studies on the Fauna of Curacao and other Caribbean Islands. **36**, 1–183.

Grassle, J. F. and J. P. Grassle, 1974: Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res., **32**, 253–284.

Habe, T., 1956: Studies on the shell remains in bays. Contr. Physiol. Ecol. Kyoto Univ., (77), 1–31. (in Japanese with English summary).

Hartman, O., 1951: The littoral marine annelids of the Gulf of Mexico. Publ. Inst. Mar.Sci., **2**, 7–124.

Hartman, O., 1974: Polychaetous annelids of the Indian Ocean including an account of species collected by members of the international Indian Ocean Expeditions, 1963-'64 and a catalogue and bibliography of the species from India. J. mar. biol. Ass. India, **16**, 191–252.

Hermans, C. O., 1979: Polychaete egg sizes, life histories and phylogeny. In "Reproductive Ecology of Marine Invertebrates", ed. S. E. Stancyk, Univ. South Carolina Press, Colombia, South Carolina, 1–9.

Imabayashi, H., 1983: Effects of oxygen-deficient water on the benthic communities. Bull. Japan Soc. Sci. Fish., **49**, 7–15. (in Japanese with English summary).

Imajima, M. and O. Hartman, 1964: The polychaetous annelids of Japan. Allan Hancock Found. Occas. Pap., **26**, 452pp.

Joh, H., Y. Hayashi and R. Miyoshi, 1969: Chemical and biological studies of water pollution in Osaka Bay. Bull. Osaka Pref. Fish. Exp. Stat., (1), 23–45. (in Japanese).

Joh, H., S. Yamochi and T. Abe, 1978a: The present condition of sediment pollution and benthic community in Osaka Bay, 1975. Bull. Osaka Pref. Fish. Exp. Stat., (5), 42–58. (in Japanese).

Joh, H., S. Yamochi and T. Abe, 1978b: Formation and decay of Oxygen-deficient water mass in Osaka Bay. Bull. Osaka pref. Fish. Exp. Stat., (5), 71–84. (in Japanese).

Kawabe, R., 1975: Benthic animals of Ago Bay. Sci. Report Shima Marineland, (3), 7–30.

Kikuchi, T., 1964: Ecology and biological production of Lake Naka-umi and adjacent regions. 3. Macro-benthic communities of Lake Shinji-ko and Lake Naka-umi. Spec. Publ. Seto Mar. Biol. Lab. Series II, Part I, 21–44.

Kikuchi, T. and M. Tanaka, 1976: Some aspects on the ecology of a short-lived semelid bivalve, *Theora lata* (Hinds), with special reference to its opportunistic life history. Physiol. Ecol. Japan, **17**, 261–271. (in Japanese with English synopsis).

Kikuchi, T. and M. Tanaka, 1978: Ecological studies on benthic macrofauna in Tomoe Cove, Amakusa. I. Community structure and seasonal change of biomass. Publ. Amakusa Mar. Biol. Lab. **4**, 189–213.

Kitamori, R., 1963: Studies on the benthos communities of littoral areas in the Seto-Inland Sea and the adjacent waters. Bull. Naikai Reg. Fish. Res. Lab., (21), 1–90. (in Japanese with

English resume).

KITAMORI, R., 1966: [Biological assessment of water pollution in sea area]. Mizushorigijutsu, **7**(4), 1–7. (in Japanese).

KITAMORI, R., 1969: [Water pollution and benthic animals in Tokyo Bay, Osaka Bay and Ise Bay]. Mizushorigijutsu, **10**(8), 15–22. (in Japanese).

KITAMORI, R., 1970: [Benthic animals and water pollution in sea area]. Kaiyō-kagaku, **2**, 643–648. (in Japanese).

KITAMORI, R., 1973: [The present condition of pollution based on benthic fauna in non-sheltered sea area]. Mizushorigijutsu, **14**(7), 21–30. (in Japanese).

KITAMORI, R., 1975: [Benthic animals as a environmental indicator——indicator organisms ——]. In "Kankyō to seibutsushihyō 2 suikaihen", ed. Nihon-seitaigakkai-kankyō-mondai-senmon' iinkai, Kyōritsu-shuppan, Tokyo, 265–273. (in Japanese).

LEPPÄKOSKI, E., 1975: Assessment of degree of pollution on the basis of macrozoobenthos in marine and brackish-water environments. Acta. Acad. abo. Ser. B. 35, 1–90.

LIGHT, W. J., 1978: Spionidae (polychaeta, annelida), Invertebrates of the San Francisco Bay estuary system. The Boxwood Press, California, 211pp.

MASUI, T., 1943: [Benthic community in Tokyo Bay]. J. Oceanogr. Soc. Japan, **3**, 130–141. (in Japanese).

MIYADI, D., 1941a: Marine benthic communities of the Beppu-wan. Mem. Imp. Mar. Obs., **7**, 483–502.

MIYADI, D., 1941b: Marine benthic communities of the Ise-wan and Mikawa-wan. Mem. Imp. Mar. Obs., **7**, 503–524.

MIYADI, D. and T. MASUI, 1942a: [Benthic communities of the Kagoshima Bay and Yamakawa Harbor]. J. Oceanogr., **13**, 751–762. (in Japanese).

MIYADI, D. and T. MASUI, 1942b: Studies on the benthic communities of the Nanao-wan. J. Oceanogr. Soc. Japan, **2**, 1–21. (in Japanese).

MIYADI, D., T. MASUI, K. YAMANE, S. KATO and S. NOMURA, 1943: [Stagnation and circulation of sea water, and the benthic animals in Habu Harbor]. Bull. Kobe Mar. Obs., (149), 46–52. (in Japanese).

MIYADI, D., T. HABE, T. IMAIZUMI, H. AMANO and K. YAMANE, 1944a: On the bay indices of the Urauti-wan with special references to the benthic and intertidal communities. J. Oceanogr. Soc. Japan, **3**, 207–215. (in Japanese).

MIYADI, D., T. MASUI and T. HABE, 1944b: [Embayment degree and community types in the bays]. Contr. Physiol. Ecol. Kyoto Univ., (3), 1–20. (in Japanese).

MONRO, C. C. A., 1930: Polychaete worms. Discovery Reports, **2**, 1–222.

NUKAI, H., 1974: Ecological studies on distribution and production of some benthic animals in the coastal waters of central Inland Sea of Japan. J. Sci. Hiroshima Univ., Ser. B, Div. 1, **25**, 1–82.

NAKAO, S., 1982: Community structures of the macro-benthos in the shallow waters in northern Japan. Mem. Fac. Fish. Hokkaido Univ., **28**, 225–304.

OCHI, T., S. NISHIO and T. OKAICHI, 1978: Anoxic water in the eastern area of Hiuchi-nada. Tech. Bull. Fac. Agr. Kagawa Univ., **29**, 297–304. (in Japanese with English summary).

OKAICHI, T., T. OCHI and M. HIRANO, 1971: Organic marine pollution in the eastern area of the Hiuchi-nada. Tech. Bull. Fac. Agr. Kagawa Univ., **23**, 104–111. (in Japanese with English summary).

OKUDA, S., 1937: Spioniform polychaetes from Japan. J. Fac. Sci. Hokkaido Univ. Ser. 6, Zool. **5**,

217–254.

PEARSON, T. H., 1971: The benthic ecology of Loch Linnhe and Loch Eil, a sea-loch system on the west coast of Scotland. III. the effect on the benthic fauna of the introduction of pulp mill effluent. J. exp. mai. Biol. Ecol., **6**, 211–233.

PEARSON, T. H., 1975: The benthic ecology of Loch Linnhe and Loch Eil, a sea-loch system on the west coast of Scotland. IV. Changes in the benthic fauna attributable to organic enrichment. J. exp. mar. Biol. Ecol., **20**, 1–41.

PEARSON, T. H. and R. ROSENBERG, 1976: A comparative study of the effects on the marine environment of wastes from cellulose industries in Scotland and Sweden. Ambiol., **5**, 77–79.

PEARSON, T. H. and R. ROSENBERG, 1978: Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev., **16**, 229–311.

REISH, D. J., 1955: The relation of polychaetous annelids to harbor pollution. Public Health Repts. Wash., **70**, 1168–1174.

REISH, D. J., 1973: The use of benthic animals in monitoring the marine environment. J. Environ. Planning Pollut. Control, **1**, 32–38.

RHOADS, D. C. and D. K. YOUNG, 1970: The influence of deposit-feeding organisms on sediment stability and community trophic structure. J. Mar. Res., **28**, 150–178.

RHOADS, D. C., 1974: Organism-sediment relations on the muddy sea floor. Oceanogr. Mar. Biol. Ann. Rev., **12**, 263–300.

RICHARDSON, M. D., 1971: Benthic macroinvertebrate communities as indicators of pollution in the Elizabeth River, Hampton Roads, Virginia. M. A. Thesis. College of William and Mary, Williamsburg, Virginia, 104pp.

ROSENBERG, R., 1976: Benthic faunal dynamics during succession following pollution abatement in a Swedish esturay. Oikos, **27**, 414–427.

SANDERS, H. L., 1958: Benthic studies in Buzzards Bay. I. Animal-sediment relations. Limnol. Oceanogr., **3**, 245–258.

SANUKIDA, S., H. OKAMOTO and M. HITOMI, 1979: [Seasonal change in benthic animal communities in Harima-nada]. Kaiyō-kagaku, **11**, 664–672. (in Japanese).

SANUKIDA, S., H. OKAMOTO and M. HITOMI, 1981: On the behavior of the indicator species of marine bottom pollution. Bull. Japan Soc. Sci. Fish., **47**, 863–869. (in Japanese with English summary).

SANUKIDA, S., H. OKAMOTO and M. HITOMI, 1984: Alternation of pollution indicator species of macrobenthos during stagnant period in Eastern Hiuchi Sound. Bull. Japan Soc. Sci. Fish., **50**, 727.

SCHROEDER, P. C. and C. O. HERMANS, 1975: Annelida: Polychaeta. In "Reproduction of Marine Invertebrates, volume III Annelids and Echiurans", ed. A. C. Giese J. S. Pearse, Academic Press, New York, San Francisco, London, 1–213.

SIMON, J. L. and D. M. DAUER, 1977: Reestablishment of a benthic community following natural defaunation. In "Ecology of Marine Benthos", ed. B. C. Coull, Univ. South Carolina Press, Columbia, South Carolina, 139–154.

SHIOZAWA, T., K. KAWANA, A. HOSHIKA, T. TANIMOTO and O. TAKIMURA, 1977: Vertical distribution of heavy metals and its seasonal variations in Beppu Bay. J. Oceanogr. Soc. Japan, **33**, 350–356. (in Japanese with English summary).

TAGHON, G. L., A. R. M. NOWELL and P. A. JUMARS, 1980: Induction of suspension feeding in spionid polychaetes by high particulate fluxes. Science, **210**, 562–564.

TAKAHASHI, J. and K. ISHIKAWA, 1976: [Sediments and benthic animals around Kashima Harbor]. Bull. Ibaragi Pref. Fish. Exp. Stn., (2), 17–42. (in Japanese).

TAMAI, K., 1980: Distribution of two characteristic benthos, *Lucinoma annulata* (bivalvia) and

Aricidea sp. (polychaeta) at the innermost and deeper part in Beppu. Bay. Bull. Nansei Reg. Fish. Res. Lab., (12), 105–114. (in Japanese with English summary).

Tamai, K., 1981: Some morphological aspects and distribution of four types of *Paraprionospio* (polychaeta: Spionidae) found from adjacent waters to western part of Japan. Bull. Nansei Reg. Fish. Res. Lab., (13), 41–58. (in Japanese with English summary).

Tamai, K., 1982: Seasonal fluctuation and growth of spionid polychaete *Paraprionospio* sp. (type A) population in Osaka Bay, Japan. Bull. Japan Soc. Sci. Fish., **48**, 401–408. (in Japanese with English summary).

Thorson, G., 1950: Reproductive and larval development of marine bottom invertebrates. Biol. Rev., **25**, 1–45.

Tsuchiya, M. and Y. Kurihara, 1976: Studies on the distribution of the macrobenthos with special reference to the movement of the fine particles at Gamō Lagoon, Miyagi Prefecture. Physiol. Ecol. Japan, **17**, 145–151. (in Japanese with English synopsis).

Tsutsumi, H. and T. Kikuchi, 1984: Study of the life history of *Capitella capitata* (Polychaeta: Capitellidae) in Amakusa, South Japan including a comparison with other geographical regions. Mar. Biol., **80**, 315–321.

Ueno, S. and G. Yamamoto, 1982: Physiological tolerance in the polychaetous annelids *Capitella capitata* and *Paraprionospio pinnata*. Benthos Res., (23), 60–68. (in Japanese with English summary).

Warren, L. M., 1976: A population study of the polychaete *Capitella capitata* at Plymouth. Mar. Biol., **38**, 209–216.

Warren, L. M., 1977: The eclogy of *Capitella capitata* in British waters. J. mar. biol. Ass. U. K., **57**, 151–159.

Yano, J., 1977: Occurrence of dissolved oxygen poor water in Hiuchi-nada area, Seto Inland Sea. Bull. Ehime Pref. Fish. Exp. Stn., (1), 9–17. (in Japanese).

Yokoyama, H., 1981: Larval development of a spionid polychaete *Paraprionospio pinnata* (Ehlers). Publ. Seto Mar. Biol. Lab., **26**, 157–170.

Yokoyama, H. and K. Tamai, 1981: Four forms of the genus *Paraprionospio* (polychaeta: Spionidae) from Japan. Publ. Seto Mar. Biol. Lab., **26**, 303–317.

Yokoyama, H., 1982: Preliminary report on the life history of *Paraprionospio* sp. (polychaeta: Spionidae) in Kumihama Bay. Benthos Res., (23), 56–59. (in Japanese).

日本産 *Paraprionospio* 属（多毛類：スピオ科）4型の形態と生態

玉 井 恭 一

よく知られた富栄養化海域の指標種 *Paraprionospio pinnata*（EHLERS, 1901）を形態的，生態的に研究した。従来単一種として取り扱われていた我が国の *P. pinnata* は外部形態，分布，生息場所選択からみて，それぞれ種として認識される4型（A, B, CI, CII）に分けることができた。これまでほとんど，または全く取り扱われていなかった多くの形質が形態区分に有効である。A型は水深20m以浅の沿岸域に，B型は閉鎖性の強い内海の泥～砂泥底域に，CI型は内湾奥から外海に至る種々の海域に，そしてCII型は外海砂泥底域にそれぞれ分布する。4型のうちA, B両型のみが富栄養化海域で高密度または高比率の分布を示す。これら2つの型は基本的にはいずれも寿命1年で，比較的固定化された生活史を持ち，有機汚染指標種によくみられる臨機応変的な（opportunistic）生活史上の特徴は示さない。水質，底質，底生動物群集の季節変動と関連させて考えると，A, B両型は溶存酸素量低下などの富栄養化海域に特有の環境条件に対する生理的な耐性が強いことと，それに加えてA型の場合には加入着底が多数の種の減少期に起るという加入のタイミングの良いことが富栄養化海域での両型の生息，繁栄をもたらしている原因であると推定された。

Appendix table 1 Number of specimens of numerically abundant species at stations 1–5 in Osaka Bay from April 18, 1979 to March 9, 1980. The figure at Stn. 1 shows the number of specimens per 0.3m², and the figures at each of the other stations show the number of specimens per 0.2m². Taxonomic groups are abbreviated as: Co; Coelenterata, Cr; Crustacea, E; Echinodermata, M; Mollusca, N; Nemertinea, P; Polychaeta, T; Tentaculata.

Station	Rank	Scientific name	Taxonomic group	1979												1980			Total	Cumulative Percentage
				Apr. 18	May 16	June 10	June 24	July 8	July 22	Aug. 12	Sept. 2	Sept. 16	Oct. 21	Nov. 25	Dec. 16	Jan. 13	Feb. 11	Mar. 9		
1	1	*Paraprionospio* sp. (type A)	P	36	98	123	55	77	375	1112	1673	1714	1742	328	7	24	15	7	7386	25.85
	2	*Euchone* sp.	P	92	793	949	1300	1130	1563	0	0	0	9	4	10	23	48	55	5976	46.77
	3	*Lumbrineris longifolia*	P	206	257	255	216	269	315	370	390	528	427	364	383	392	411	531	5314	65.37
	4	*Cirriformia tentaculata*	P	5	0	8	0	1	132	421	375	337	202	50	4	10	7	13	1565	70.85
	5	*Sigambra tentaculata*	P	43	47	86	47	71	71	100	137	113	83	141	142	80	107	56	1324	75.48
	6	*Pseudopolydora* sp.	P	3	22	99	168	243	255	0	0	0	0	1	0	0	1	1	801	78.29
	7	*Glycinde* sp.	P	45	32	28	40	54	92	74	118	120	82	23	12	10	23	12	765	80.97
	8	*Prionospio cirrifera*	P	95	58	37	53	53	47	18	131	5	0	4	15	1	3	11	531	82.82
	9	*Polydora ciliata*	P	0	0	51	9	36	37	39	50	282	0	0	0	0	0	0	504	84.59
	10	Phoronidea sp.	T	15	9	8	4	2	6	7	20	40	72	40	30	29	53	76	411	86.03
	11	*Theora lubrica*	M	1	9	4	38	117	207	0	0	0	0	0	0	0	0	0	376	87.34
	12	*Spiochaetopterus costarum*	P	10	2	9	2	2	5	3	23	33	43	66	34	10	19	24	285	88.34
	13	*Musculus senhausia*	M	32	56	59	66	18	32	3	0	0	0	0	0	0	0	0	266	89.27
	14	*Corophium acherusicum*	Cr	1	26	52	135	37	2	0	0	0	0	0	0	0	0	1	254	90.16
	14	Hexacorallia sp.	Co	23	30	42	30	15	19	8	20	17	13	6	6	8	6	11	254	91.05
	16	*Ophiophragmus japonicus*	E	2	64	62	57	32	29	5	0	0	0	0	0	0	0	1	252	91.93
	17	Capitellidae sp.	P	0	1	0	2	5	6	8	15	3	0	3	21	23	46	84	217	92.69
	18	*Raete rostralis*	M	1	19	37	38	67	48	0	0	0	0	1	0	0	0	0	211	93.43
	19	Nemertinea sp.	N	7	16	25	14	27	22	9	0	13	3	2	5	1	1	7	152	93.96
	20	*Nectoneanthes* sp.	P	12	4	6	5	2	9	0	0	0	8	32	5	9	6	6	104	94.33
2	1	*Paraprionospio* sp. (type A)	P	295	180	1	35	2	1	0	0	2	1	1	0	3	0	0	521	43.34
	2	*Euchone* sp.	P	12	9	35	40	53	35	16	0	0	0	0	0	2	1	0	203	60.23
	3	*Sigambra tentaculata*	P	10	21	23	7	3	1	0	1	3	5	1	6	17	3	9	110	69.38
	4	*Lumbrineris longifolia*	P	9	8	2	4	4	2	0	1	2	0	2	3	5	1	1	44	73.04
	5	*Macoma tokyoensis*	M	1	2	2	8	0	2	6	2	3	2	1	2	1	3	5	40	76.37
	6	*Paraprionospio* sp. (type B)	P	0	0	2	5	1	3	0	0	0	0	2	2	12	5	6	38	79.53
	7	*Glycinde* sp.	P	3	1	1	5	2	2	2	4	3	1	3	1	4	0	2	34	82.36
	8	Copepoda sp.	Cr	0	1	7	11	0	0	0	0	0	0	0	0	0	3	1	23	84.28
	9	*Oxydromus* sp.	P	4	2	2	3	1	8	0	2	0	1	0	2	1	1	3	21	86.02
	10	*Theora lubrica*	M	1	7	2	2	0	4	2	1	0	0	0	0	0	0	0	19	87.60
3	1	*Paraprionospio* sp. (type B)	P	8	3	3	10	3	0	0	0	0	0	2	0	1	4	3	37	14.12
	2	*Sigambra tentaculata*	P	0	1	1	0	2	1	0	3	1	0	3	2	3	2	5	24	23.28
	3	*Echinocardium cordatum*	E	0	0	0	1	6	3	1	3	2	0	0	2	0	0	0	18	30.15
	4	*Euchone* sp.	P	11	0	2	1	0	1	0	0	0	0	0	0	0	0	0	16	36.26
	4	*Theora lubrica*	M	4	2	1	2	1	2	4	0	0	0	0	0	0	0	0	16	42.37
	4	Capitellidae sp.	P	1	2	2	1	2	0	0	1	1	3	0	2	0	1	0	16	48.47
	7	*Spiochaetopterus costarum*	P	0	0	0	0	0	0	0	1	0	0	1	1	3	6	2	14	53.82
	7	*Poecilochaetus japonicus*	P	2	0	3	3	1	0	1	4	0	0	0	0	0	0	0	14	59.16

	Glycinde sp.	P	1	1	1	1	2	1	0	0	0	0	1	1	0	0	0	9	62.60	
	10 Holothuroidea sp.	E	0	0	0	2	4	0	1	0	0	0	0	0	1	0	0	8	65.65	
	1 *Theora lubrica*	M	2	3	3	6	13	143	17	8	3	1	0	0	0	0	3	204	25.31	
	2 *Euclymene* sp.	P	1	2	13	7	28	10	11	1	14	3	3	2	0	1	2	98	37.47	
	3 *Sternaspis scutata*	P	0	1	7	2	9	18	0	0	2	0	0	2	2	6	2	51	43.80	
	4 *Sigambra tentaculata*	P	1	1	4	2	3	1	4	2	0	0	10	6	5	7	4	50	50.00	
	5 *Glycinde* sp.	P	6	6	3	2	5	3	2	3	6	1	2	2	0	1	0	42	55.21	
4	6 *Poecilochaetus japonicus*	P	3	4	11	0	4	3	5	0	2	0	0	0	0	1	0	33	59.31	
	7 *Echinocardium cordatum*	E	1	2	4	2	2	1	2	1	6	2	1	1	1	1	0	27	62.66	
	8 Hexacorallia sp.	Co	0	1	1	6	2	4	4	0	0	0	1	0	0	0	0	19	65.01	
	9 *Nephtys polybranchia*	P	1	3	2	3	4	4	0	0	0	0	0	0	0	0	1	18	67.25	
	10 *Euchone* sp.	P	4	11	0	0	0	0	0	0	0	0	0	0	0	0	0	15	69.11	
	(*Paraprionospio* sp. (type B))	P	0	1	0	3	2	0	0	1	0	0	2	0	1	2	0	12		
	1 *Euclymene* sp.	P	7	11	12	16	2	21	0	2	4	6	2	3	5	3	10	104	12.31	
	2 *Glycinde* sp.	P	9	5	22	6	3	6	0	2	4	3	5	7	0	3	1	76	21.30	
	3 *Ophiophragmus japonicus*	E	1	0	45	0	1	10	0	0	0	0	0	0	0	0	0	57	28.05	
	4 *Theora lubrica*	M	0	0	0	15	23	6	8	1	0	0	0	0	0	0	0	53	34.32	
5	5 Holothuroidea sp.	E	0	3	0	8	8	3	8	5	5	1	1	2	2	2	0	48	40.00	
	6 Hexacorallia sp.	Co	1	5	10	7	0	16	0	1	0	0	0	0	1	4	1	46	45.44	
	7 *Terebellides stroemi*	P	0	1	9	7	0	14	0	0	1	3	0	0	1	0	1	37	49.82	
	8 *Sigambra tentaculata*	P	3	4	2	1	0	2	0	2	1	1	4	5	1	5	0	31	53.49	
	9 *Paraprionospio* sp. (type B)	P	1	2	11	3	0	2	0	0	0	0	1	2	1	0	1	24	56.33	
	9 *Praxillella affinis*	P	0	0	5	1	0	7	0	5	0	1	0	0	0	0	5	24	59.17	

Appendix table 2 Number of specimens of numerically abundant species at Stn. L in Tosa Bay from April 22, 1980 to July 8, 1981.
The figure shows the number of specimens per 0.2m². Taxonomic groups are abbreviated as: Cr; Crustacea, M; Mollusca, N; Nemertinea, P; Polychaeta.

Rank	Scientific name	Taxonomic group	1980									1981							Total	Cumulative Percentage
			Apr. 22	May 28	June 30	July 28	Aug. 25	Sept. 25	Oct. 27	Nov. 26	Dec. 23	Jan. 14	Feb. 18	Mar. 5	Apr. 8	May 13	June 8	July 8		
1	*Umbonium costatum*	M	0	0	0	0	0	0	0	160	52	52	20	19	22	0	0	0	325	11.99
2	*Prionospio* sp.	P	31	56	59	54	16	3	1	1	7	12	7	8	2	7	2	2	268	21.87
3	*Ampelisca brevicornis*	Cr	4	10	87	33	10	4	0	0	5	21	35	10	0	6	0	2	227	30.25
4	*Veremolpa micra*	M	19	4	2	1	10	0	0	0	2	14	23	24	19	2	2	47	169	36.48
5	*Pontocrates altamarinus*	Cr	29	3	13	16	1	1	0	1	15	20	0	4	3	12	7	7	132	41.35
6	*Spiophanes* sp.	P	38	14	15	10	17	5	7	0	2	5	3	7	0	0	0	0	123	45.89
7	*Moerella nishimurai*	M	4	0	0	0	18	1	10	6	5	7	6	10	4	5	2	15	93	49.32
8	Nemertinea sp.	N	16	19	5	16	11	6	1	0	3	6	3	0	1	1	0	1	89	52.60
9	*Harpinia miharaensis*	Cr	0	4	3	5	0	1	5	18	7	2	0	10	4	1	10	13	83	55.66
10	Mysidacea sp.	Cr	5	10	2	3	0	1	0	12	8	2	0	2	7	6	2	15	75	58.43
11	*Paraprionospio* sp. (type A)	P	9	3	1	8	35	11	0	1	0	1	2	1	1	1	0	0	74	61.16
12	*Moerella jedoensis*	M	5	6	8	11	6	11	0	0	0	1	1	0	1	0	0	2	52	63.08
13	*Leptochela gracilis*	Cr	1	0	5	1	17	2	0	8	7	2	0	2	1	1	2	0	49	64.88
14	*Ogyrides striaticauda*	Cr	3	2	0	6	9	3	0	2	1	0	3	3	9	5	1	1	48	66.65
15	*Saccella confusa*	M	5	7	19	7	2	1	0	0	1	0	1	2	1	1	0	0	47	68.39
16	*Lumbrineriopsis* sp.	P	0	0	0	0	0	0	0	13	13	0	0	0	0	0	11	2	39	69.83
17	*Spio filicornis*	P	1	4	11	4	0	0	0	0	1	2	3	3	0	5	2	1	37	71.19
18	*Corophium* sp.	Cr	15	4	2	4	0	0	0	1	3	2	4	0	0	1	0	0	36	72.52
19	*Glycera subaenea*	P	4	1	0	5	3	0	1	1	2	2	6	5	1	2	0	2	35	73.81
19	*Conotalopia* sp.	M	22	0	5	3	0	0	0	0	0	1	0	3	1	0	0	0	35	75.10

別 途 発 表 業 績

Titles and abstracts of separately issued contributions

播磨灘における *Chattonella* 耐久細胞の分布と発芽温度

今井　一郎・伊藤　克彦・安楽　正照

Distribution of dormant cells of *Chattonella* in Harima-Nada, eastern Seto Inland Sea, and temperature characteristics of germination by Ichiro IMAI, Katsuhiko ITOH and Masateru ANRAKU

1984年5月14日受理　業績148号
日本プランクトン学会報　**31**(1), 35—42, (1984) に掲載

抄　　録

1983年4月に播磨灘の22定点から柱状採泥器によって得た底泥試料をろ過海水で培養し，出現した *Chattonella* の栄養細胞数を耐久細胞数と見なして種々の実験を行なった。

Chattonella の栄養細胞は底泥の 100μm 以下の画分から出現し，30—58μm の画分で全体の約70%を占めた。栄養細胞は底泥の培養開始後2日目から出現し，4—6日目の3日間で全体の70%以上，7日目までで90%以上に達した。底泥から栄養細胞は15—25℃の実験温度内ですべて出現し，その割合は15℃と18℃で少なく，20℃から増加して22℃で最大となり，25℃では減少した。耐久細胞からの発芽には温度が重要な要因であり，光は以後の栄養細胞の生存や増殖に必要であるに過ぎないようである。播磨灘において耐久細胞は0—65細胞・g^{-1} 湿泥の密度で存在し，その分布は均一でなく，徳島県沿岸と灘中央部に高密度に存在していた。1981—83年に実施した広島湾（阿多田島沖）での *Chattonella* の出現に関する調査で，*Chattonella* 栄養細胞は春から夏の水温上昇期に底層水温が約20℃前後に達した時に初めて表層で確認された。

現時点において *Chattonella* の耐久細胞の形態は不明であり，その確認同定が緊急の課題であることは言うまでもない。しかし，本研究で述べた培養技法を用いることにより，*Chattonella* 赤潮の発生する海域で，そのたね場を推定することは可能であろう。さらに，各海域において春から夏にいたる水温上昇期に，底層水温の推移を監視し，必要に応じて栄養細胞を計数することによって，赤潮発生の第一段階である初期個体群の出現を確認することは，赤潮発生予知の手段の1つとして有効であると思われる。

アイナメ仔稚魚における鱗形成過程（英文）

福原　修・伏見　徹

Squamation of larval greenling *Hexagrammos otakii* (Pisces: Hexagrammidae) reared in laboratory by Osamu FUKUHARA and Toru FUSHIMI

1984年10月3日受理　業績155号
日本水産学会誌　50(5), 759—761, (1984) に掲載

抄　　録

アイナメの鱗の出現と成長に伴う形成過程を知るため，飼育して得た標準体長20～56㎜の標本約100尾をアリザリン染色し，顕微鏡下で観察した。

鱗は体長27～32㎜の間に側線上の軀幹前端部と尾柄部に発生する。仔稚魚の成長に伴い鱗域を各方向に拡げ，体長35㎜頃には体側の約半分が覆われ，体長53㎜以上で体表全面が鱗で覆われる。成長に伴う鱗の形成過程を図示し，仔稚魚期における鱗の役割について若干の考察を加えた。

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